Indian and Northern Affairs Canada
Affaires indiennes et du Nord Canada

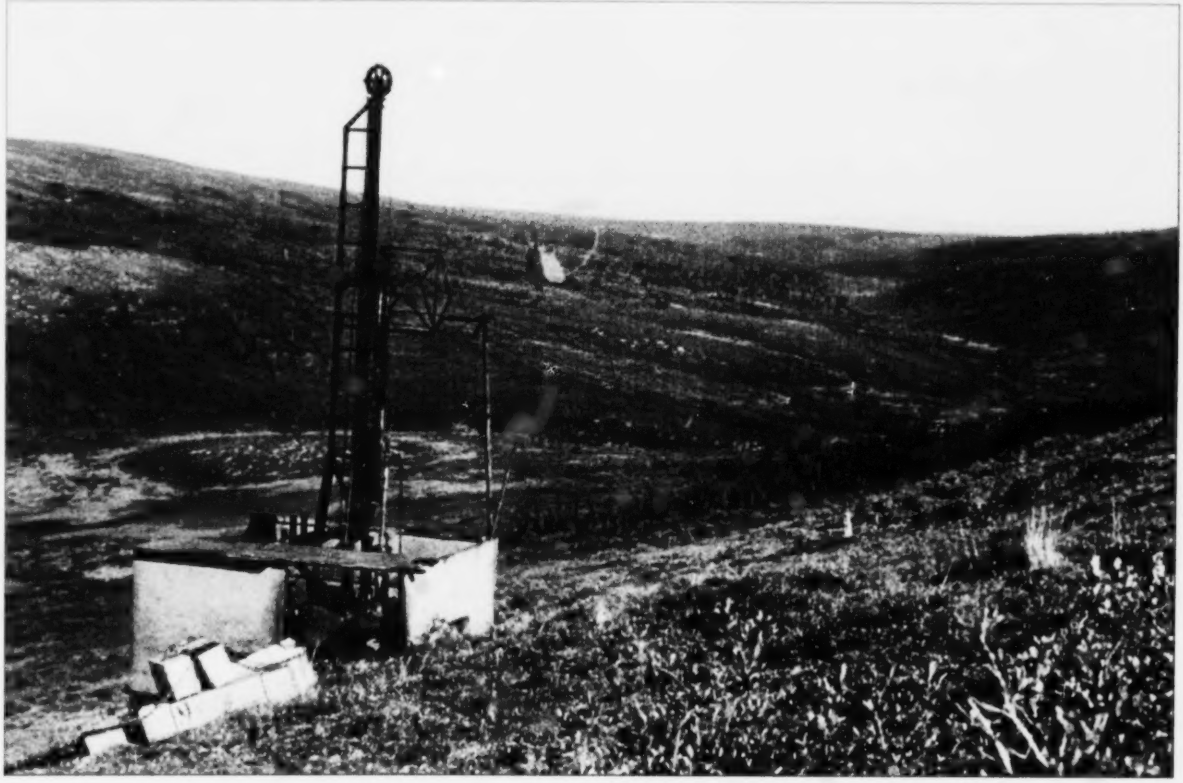
Exploration and Geological Services Division, Yukon Region

BULLETIN 12

Volcanic-associated massive sulphide (VMS) mineralization in the Yukon-Tanana Terrane and coeval strata of the North American miogeocline, in the Yukon and adjacent areas

J.A. Hunt

with contributions from
C.H.B. Leitch and M. Orchard



Canada

YUKON
GEOLOGY PROGRAM

Yukon
Economic Development

BULLETIN 12

Volcanic-associated massive sulphide (VMS) mineralization in the Yukon-Tanana Terrane
and coeval strata of the North American miogeocline, in the Yukon and adjacent areas

J.A. Hunt

103-06126/

Exploration and Geological Services Division

Bulletin 1 The Whitehorse Copper Belt: Mining Exploration and Geology 1967 - 1980 (105D)
D. Tenney

Bulletin 2 Geology and Genesis of the Mount Skukum Epithermal Gold-Silver Deposits, Southwestern Yukon Territory (105D)
B.W.D. McDonald

Bulletin 3 Shape and Composition of Lode and Placer Gold from the Klondike District, Yukon, Canada (115O, parts of 116B)
J.B. Knight, J.K. Mortensen and S.R. Morison

Bulletin 4 Sedimentology of Placer Gravels near Mt. Nansen, Central Yukon Territory (115I)
W.P. LeBarge

Bulletin 5 Natural Land Reclamation for Mineral Exploration Properties and Placer Mines in Yukon
C. Mougeot

Bulletin 6 Geology of the McQuesten River region, Northern McQuesten and Mayo Map Areas, Yukon Territory (115P/14-16, 105M/13-14)
Donald C. Murphy

Bulletin 7 Geology of the Mayo Map Area, Yukon Territory (105M)
Charlie Roots

Bulletin 8 A Transect Across Northern Stikinia: Geology of the Northern Whitehorse Map Area, Southern Yukon Territory (105D/13-16)
Craig J.R. Hart

Bulletin 9 Geology of the Upper Hart River Area, Eastern Ogilvie Mountains, Yukon Territory (116A/10, 11)
Grant Abbott

Bulletin 10 Geology and mineral occurrences of the Slats Creek, Fairchild Lake and "Dolores Creek" areas, Wernecke Mountains (106D/16, 106C/13, 106C/14), Yukon Territory
Derek J. Thorkelson

Bulletin 11 Quaternary geology and till geochemistry of the Anvil district (parts of 105K/2, 3, 5, 6 and 7), central Yukon Territory
Jeffrey D. Bond

Bulletin 12 Volcanic-associated massive sulphide (VMS) mineralization in the Yukon-Tanana Terrane and coeval strata of the North American miogeocline, in the Yukon and adjacent areas
J.A. Hunt

Bulletin 13 Placer gold deposits of the Mayo area, central Yukon
W.P. LeBarge, J.D. Bond and F.J. Hein

Copies available from: Geoscience Information and Sales, c/o Whitehorse Mining Recorder,
Indian and Northern Affairs Canada, 102-300 Main St., Whitehorse, Yukon, Y1A 2B5
Phone (867) 667-3266, Fax (867) 667-3267, geosales@inac.gc.ca
Visit our web site: www.geology.gov.yk.ca

Exploration and Geological Services Division, Yukon Region

BULLETIN 12

Volcanic-associated massive sulphide (VMS) mineralization in the Yukon-Tanana Terrane and coeval strata of the North American miogeocline, in the Yukon and adjacent areas

J.A. Hunt[1]

with contributions from
C.H.B. Leitch[2] and M. Orchard[3]

[1]Yukon Geology Program, Whitehorse, Yukon, Canada
[2]Vancouver Petrographics, Vancouver, British Columbia, Canada
[3]Geological Survey of Canada, Vancouver, British Columbia, Canada

2002

Published under the authority of the Minister of Indian Affairs and Northern Development, Ottawa, 2002.
http://www.inac.gc.ca
Printed in Whitehorse, Yukon, 2002

© Minister of Public Works and Government Services Canada

QS-Y194-000-EE-A1 Catalogue No. R2-213/2002E ISBN 0-662-32198-7

This, and other Yukon Geology Program publications, may be obtained from:
Geoscience and Information Sales
c/o Whitehorse Mining Recorder
102-302 Main Street
Whitehorse, Yukon Y1A 2B5 Canada
phone (867) 667-3266, fax (867) 667-3267, geosales@inac.gc.ca
Visit the Yukon Geology Program web site at www.geology.gov.yk.ca

In referring to this publication, please use the following citation:
Hunt, J.A., 2002. Volcanic-associated massive sulphide (VMS) mineralization in the Yukon-Tanana Terrane and coeval strata of the North American miogeocline, in the Yukon and adjacent areas. Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Bulletin 12, 107 p.

Production by K-L Services, Whitehorse, Yukon.

Cover: Diamond drilling at the Kudz Ze Kayah deposit in the Finlayson Lake district.
Photo from Paul MacRobbie (Teck-Cominco).

Preface

A study of volcanic-associated massive sulphide (VMS) mineralization in the central and southeastern Yukon was initiated in 1996 by Julie Hunt, DIAND Mineral Deposits Geologist. This project was close on the heels of the largest mineral claim staking rush the Territory has ever seen. Interest centred on the Finlayson Lake area and spread to all associated stratigraphy in the Yukon-Tanana Terrane and to coeval strata of the North American miogeocline.

The study describes the geology, petrology and geochemistry of known VMS mineral deposits and occurrences in the above terranes in the Yukon, and summarizes information on VMS deposits from contiguous Alaska and northern British Columbia. The detailed summaries and database shed light on the mineral deposit settings and allow updating of mineral deposit models.

This was a unique opportunity to work in this mineral belt during a surge in exploration activity. It allowed the author to take advantage of the availability of exploration company geologist's expertise, the abundance of mineral assessment reports summarizing the new geological work, plus new government geological mapping and university research in the area. This study could not have been completed without the cooperation and support of exploration companies and individuals working in these areas; their assistance is greatly appreciated.

Grant Abbott
Chief Geologist and Regional Manager
Exploration and Geological Services Division
Indian and Northern Affairs Canada (DIAND)

Rod Hill
Manager, Mineral Resources Branch
Department of Energy, Mines and Resources
Yukon Government

Préface

Une étude de la minéralisation en sulfures massifs volcanogènes (SMV) dans le centre et le sud-est du Yukon a été entreprise en 1996 par Julie Hunt, géologue spécialisée dans l'étude des gîtes minéraux au MAINC. Ce projet a suivi de près la plus grande ruée au jalonnement de claims miniers jamais vue dans le Territoire. L'intérêt était centré sur les environs du lac Finlayson et s'est étendu à toute la stratigraphie associée dans le Terrane de Yukon-Tanana et les strates contemporaines du miogéoclinal de l'Amérique du Nord.

L'étude décrit la géologie, la pétrologie et la géochimie des gîtes minéraux de SMV et des occurrences dans les terranes du Yukon susmentionnés, et résume l'information relative aux gîtes de SMV dans les régions voisines en Alaska et dans la partie septentrionale de la Colombie-Britannique. Les résumés détaillés et les bases de données donnent de l'information sur le cadre des gîtes minéraux et permettent de mettre à jour les modèles des gîtes.

Il s'agissait d'une occasion unique de travailler dans cette ceinture minérale pendant une période d'intensification de l'activité d'exploration. Ce projet a permis à l'auteur d'avoir accès à l'expertise de géologues de sociétés privées, à une myriade de rapports d'évaluation des ressources minérales synthétisant les travaux récents en géologie, ainsi qu'aux données des plus récents programmes gouvernementaux de cartographie géologique et universitaires de recherche dans ce domaine. Cette étude n'aurait pas pu être menée à bien sans la collaboration et le soutien des sociétés d'exploration et des personnes travaillant dans ces régions. Leur appui est grandement apprécié.

Grant Abbott
Géologue en chef et gestionnaire régional
Division des services géologiques et d'exploration
Affaires indiennes et du Nord Canada (MAINC)

Rod Hill
Gestionnaire, Division des ressources minérales
Ministère de l'Énergie, des Mines et des Ressources
Gouvernement du Yukon

ACKNOWLEDGEMENTS

Colin Godwin critically reviewed this manuscript and I am indebted to him for providing many helpful suggestions and revisions. Thanks are extended to Terry Tucker of Expatriate Resources Ltd. for reviewing the sections on the Wolverine, Kudz Ze Kayah and Ice deposits, to Paul MacRobbie of Cominco Ltd. for reviewing the sections on the Kudz Ze Kayah deposit and various other properties owned by Cominco in the Finlayson Lake and Dawson areas, to Rob Carne of Archer Cathro and Associates (1981) Ltd. for reviewing properties in the Dawson area, to Peter Holbek and Rob Wilson of Atna Resources Ltd. for reviewing the sections on the Wolf and Marg deposits and the Tree property, and to Chuck Downey of Eagle Plains Resources Ltd. for reviewing the section on the Bnob (Ice) and Chzerpnough (Fire) properties. The permission of these companies to publish confidential data is appreciated.

Jason Adams is thanked for drafting many of the figures. Able and enthusiastic field assistance was provided by Will Zantvoort, Jay Timmerman, Jason Adams, Vickki Meyer and Grant Redfern. Trans North Helicopters, especially pilot John Witham, provided competent helicopter service. Bonanza Aviation Ltd., Action Aviation, and Black Sheep Aviation and Cattle Co. provided able fixed wing service.

All companies involved in VMS exploration in the Yukon during the last few years are thanked for their generous hospitality and their sharing of, and access to information. These include staff of Columbia Gold Mines Ltd., Expatriate Resources Ltd., Atna Resources Ltd., Westmin Resources Ltd., NDU Resources Ltd., Equity Engineering Ltd., Anvil Range Corp., Cominco Ltd., Eagle Plains Resources Ltd., YGC Resources Ltd., Aurum Geological Ltd., and Tanana Exploration Inc. Warm hospitality was provided by Bert Savage at his placer camp in the Matson Creek area. Informative discussions took place with staff of the Yukon Geology Program plus Ron Berdhal, Colin Dunn, Cynthia Dusel-Bacon, Mark Fedikow, Jim Franklin, Ray Lett, Jim Mortensen, Chris Sebert, Steve Sibbick, Lee Pigage, Robert Stroshein, Dirk Tempelman-Kluit, John Thompson and Derek Thorkelson. Staff of Columbia Gold Mines Ltd. gave us an introduction to the Fyre Lake deposit in 1996 and continued assistance throughout this project. Staff of Westmin Resources Ltd. and Cominco Ltd. toured us through the Wolverine and Kudz Ze Kayah deposits in 1996. Terry Tucker of Expatriate Resources Ltd. assisted with a very informative updated version of the tour in 2000. Kate Bull gave us an introduction to VMS deposits in the Robertson River area of Alaska. Jim Mortensen provided a valuable introduction to many of the occurrences in the Dawson area.

Funding provided to the Yukon Geology Program by the Department of Indian Affairs and Northern Development, Canada, and the Yukon Territorial Government made this study possible.

Contents

Preface/Préface ... i
Acknowledgements ... ii
Abstract/Resumé ... ix
Introduction ... 1
Yukon-Tanana Terrane ... 4
  Summary of Geology ... 4
  Finlayson Lake District ... 4
    Geology ... 4
      Mineralization ... 7
    Preliminary lithogeochemistry ... 7
      - Fire Lake mafic metavolcanic unit (unit DMF/Unit 2) ... 7
      - Kudz Ze Kayah felsic metavolcanic unit (unit MK/Unit 3) ... 9
      - Campbell Range belt ... 9
    Summary of mineralization ... 11
      Geochemical and geophysical information ... 11
        Stream and soil geochemistry ... 11
        Drift prospecting and till geochemistry ... 11
        Regional geophysics ... 12
    Mineral deposits ... 12
      Fyre Lake ... 12
        Property geology ... 12
        Lithogeochemistry ... 20
        Deposit description ... 20
        - East Kona zone - lower horizon ... 23
        - East Kona zone - upper horizon ... 23
        - West Kona zone ... 25
        Exploration techniques ... 27
      Kudz Ze Kayah ... 27
        Property geology ... 27
        - ABM deposit ... 27
        - GP4F deposit ... 28
        - Fault Creek Zone ... 28
        Exploration techniques ... 28
      Wolverine ... 28
        Property geology ... 32
        Deposit geology ... 33
        Mineralization ... 34
        Zonation ... 36
        Hydrothermal alteration ... 36
        Interpretation ... 37
        Exploration techniques ... 38
        Wolverine and Kudz Ze Kayah metallurgy ... 38
      Ice ... 39
        Property geology ... 39
        Deposit description ... 44
        Exploration techniques ... 46

Significant mineral occurrences 46
1) Within the Grass Lakes succession 46
Pack (Pak) 46
Blueline 47
Pneumonia (Mony) 47
Akhurst (Expo) 47
Ant (Hat Trick) 48
Goal-Net 48
Red Line 48
Cobb 48
League 49
Nad 49
2) Within the Campbell Range succession 49
Money (Julia) 49
Geology 49
Mineralization 50
Exploration techniques 50
3) Within rocks of unknown affinity 50
Hoo (Argus) 50
El (Tin) 51
Eldorado 51
Py (Ty) 52
Dawson Area, Yukon 52
Geology 52
Main mineral occurrences 54
Base metal occurrences in Late Devonian to mid-Mississippian Nasina Assemblage 54
Clip, Mickey, Mort and Holly 54
Pup 54
Fan, Coal, Bruin and Swde 56
Base metal occurrences in Permian Klondike Schist 56
Matson Creek 56
Baldy (Bal) and Pub 57
Bronson 58
Floc 58
Base metal occurrences in rocks of unknown affinity (either Klondike Schist or Nasina Assemblage) 59
Top 59
Fresno 59
River 59
Exploration techniques 59
Stream sediment and soil sampling 60
Biogeochemical sampling 60
Geophysics 62
Summary of VMS Occurrences in the Yukon-Tanana Terrane in Alaska 62
Delta district 62
Trident Glacier district 63
Bonnifield district 64
Other 64
Sumdum Glacier mineral belt 64
Ketchikan area 64
Liberty area 64

South-central Yukon and northern British Columbia 65
- **Teslin-Rancheria area** 65
  - Mor 65
  - Caribou Creek 65
  - Cabin Lake 65
  - Bar (Eng) 67
  - Iron Creek (Big Top) 67
  - Bar (Dan, Swift River) 67

Glenlyon area 68

North American Miogeocline 69

History and geology of the North American miogeocline 69

Pelly-Cassiar Platform 69
- **Geology** 69
  - Metamorphism and alteration 70
  - Structure 70
- **Geochemistry** 70
- **Main mineral occurrences/deposits** 71
  - Wolf 71
    - Property geology and mineralization 71
    - Exploration techniques 71
  - MM 74
    - Mineralization 74
  - Chzerpnough (Fire) 76
    - Geology 76
    - Exploration techniques 77
  - Tree 77
    - Mineralization 79
    - Geochemistry and geophysics 79
  - Bnob (Ice) 79
    - Geology 79
    - Mineralization 79
  - Mamu 80
  - Vermilion 80

Selwyn Basin 80
- **Mineral deposits/occurrences** 80
  - Marg 80
    - Property and deposit geology 80
    - Preliminary lithogeochemistry 85
    - Exploration techniques 88
  - Jane 88
- **VMS potential in Selwyn Basin rocks** 88

Summary 90
- **Mineralization** 90
- **Exploration potential** 92

References 93

Figures

Figure 1. Location of significant VMS deposits in the Yukon 1

Figure 2. Distribution of the Yukon-Tanana Terrane, Kootenay, Nisling, Dorsey, and Slide Mountain terranes, Big Salmon complex and Campbell Range belt 3

Figure 3. Evolution of nomenclature for metasedimentary and metavolcanic rocks in the Finlayson Lake area 6

Figure 4. Geology of the Finlayson Lake area modified from Murphy and Piercey (1999b). ..... in pocket

Figure 5. VMS deposits and mineral occurrences of the Finlayson Lake area 8

Figure 6. Discrimination diagrams and chondrite-normalized REE plots for the Fire Lake metavolcanic unit, the Kudz Ze Kayah felsic metavolcanic unit and Campbell Range Belt rocks in the Finlayson Lake area 10

Figure 7. Regional silt sample survey results for the Finlayson Lake map area (105G) 13, 14, 15

Figure 8. Results of till geochemical analysis in the Wolverine Lake area 16

Figure 9. a) Fyre Lake bedrock geology map, and b) enlargement of the Kona deposit area 18, 19

Figure 10. Fyre Lake deposit photographs 21

Figure 11. Discrimination diagrams and chondrite-normalized REE plots for mafic metavolcanic rocks from the Fyre Lake property 22

Figure 12. Kona deposit sections 24

Figure 13. Fyre Lake deposit photographs 26

Figure 14. Photographs for the Kudz Ze Kayah area 29

Figure 15. Cross section through the ABM deposit, Kudz Ze Kayah property 30

Figure 16. Bedrock geology map of the Kudz Ze Kayah area 31

Figure 17. Map of the Wolverine property 33

Figure 18. Generalized stratigraphic section for the Wolverine deposit 34

Figure 19. Geological cross section 16700E through the Wolverine zone 35

Figure 20. Photographs for the Wolverine property 36

Figure 21. Surface projection of true thickness contours of massive sulphide mineralization 37

Figure 22. Wolverine deposit: a) Cu and Zn geochemistry, and b) Pb and Ba geochemistry 38

Figure 23. General process flowsheet for ore from the Kudz Ze Kayah and Wolverine deposits 39

Figure 24. Bedrock geology map for the Ice deposit 40

Figure 25. Simplified stratigraphic column for the Ice deposit 41

Figure 26. Photographs for the Ice deposit 43

Figure 27. Ice deposit 45

Figure 28. Photographs for the Money (Julia) property 51

Figure 29. Location of the Finlayson Lake district after restoration of strike-slip movement on the Tintina Fault 53

Figure 30. Bedrock geology and regional silt sample survey results for the Dawson area 55

Figure 31. Copper, lead and zinc biogeochemical and soil sampling results for the Matson Creek property 61

Figure 32. Present location of the Pelly-Cassiar Platform and Selwyn Basin 66

Figure 33. Photographs for the southern end of the Pelly Mountain volcanic belt 72

Figure 34. Wolf deposit 73

Figure 35. Photographs for the MM, Bnob (Ice), Chzerpnough (Fire) and Marg occurrences 75

Figure 36. Stratigraphic section for the Tree property 78

Figure 37. Location of the Marg VMS deposit and Jane zone 81

Figure 38. Bedrock geology map of the Marg deposit 82

Figure 39. Drill sections 2000E amd 2100E for the Marg deposit 83

Figure 40. Discrimination diagrams and chondrite-normalized REE plot for rocks from the Marg Deposit 86

Figure 41. Re-interpreted drill section 2100E for the Marg deposit 88

Tables

Table 1. Recently discovered (or expanded) Cu-Zn and Zn-Pb-Cu type VMS deposits in the Yukon compared to the Canadian average 2
Table 2. Lead, zinc and copper values in soils from VMS mineral occurrences hosted by Devono-Mississppian rocks 60
Table 3. Lead, zinc and copper values in soils from VMS mineral occurrences hosted by probable Carboniferous to Permian rocks 60
Table 4. VMS mineralization in YTT rocks in Alaska 63
Table 5. Age of VMS mineralization host rocks in the Yukon-Tanana Terrane 92

Appendices (CD) in pocket

1. Lithogeochemical Analyses
2. Inductively Coupled Plasma (ICP) Analyses and Descriptions for Mineralized Specimens
3. Petrography of Thin and Polished Sections
4. Geochronology
5. Portable Infrared Mineral Analyser (PIMA) Analyses

ABSTRACT

Discovery of the volcanic-associated massive sulphide (VMS) Kudz Ze Kayah (KZK) deposit in 1994, closely followed by the discovery of the Wolverine VMS deposit, resulted in a period of intense exploration activity in the Yukon. This led to the discovery of additional VMS mineralization that includes GP4F, Ice and significant new reserves at Fyre Lake. Numerous VMS prospects were identified.

The Fyre Lake, KZK, GP4F, Wolverine, and Ice VMS deposits are hosted by the Yukon-Tanana Terrane (YTT) in the Finlayson Lake district of southeastern Yukon. The Fyre Lake deposit (8 200 000 tonnes of 2.1% Cu and 0.73 g/t Au) is stratigraphically lowest and occurs in mafic metavolcanic rocks of the Devonian to Mississippian Grass Lakes succession. The KZK and GP4F deposits (13 000 000 tonnes of 5.5% Zn, 1% Cu, 1.3% Pb, 125 g/t Ag and 1.2 g/t Au and 1 500 000 tonnes of 6.4% Zn, 3.1% Pb, 0.1% Cu, 89.7 g/t Ag and 2.0 g/t Au, respectively) are within the Devonian to Mississippian succession but lie stratigraphically above Fyre Lake in felsic metavolcanic rocks. The Wolverine deposit (6 237 000 tonnes of 12.66% Zn, 1.33% Cu, 1.55% Pb, 370.9 g/t Ag and 1.76 g/t Au) is hosted by Carboniferous rhyolitic metavolcanic rocks and carbonaceous argillite of the Wolverine succession. The Ice deposit (4 561 863 tonnes of 1.48% Cu) occurs highest in the stratigraphy and is hosted within late Palaeozoic mafic metavolcanic and associated metasedimentary rocks of the Campbell Range succession.

The YTT underlies a large part of the Yukon, east-central Alaska and parts of British Columbia. VMS mineralization occurs within rocks of the YTT in the Dawson and Glenlyon areas of the Yukon, in the Teslin-Rancheria area in the Yukon and adjacent British Columbia, and in several areas within Alaska, as well as in the Finlayson Lake area of the Yukon. In the Dawson area, which lays adjacent to the massive-sulphide-rich Finlayson Lake district (before approximately 425 km of right lateral movement on the Tintina Fault), VMS prospects are hosted in Late Devonian to mid-Mississippian Nasina Assemblage and Permian Klondike Schist. In the Glenlyon area, massive sulphide mineralization and chert horizons occur within a belt of rocks that is at least 20 km long. In the Teslin-Rancheria area and adjacent northern British Columbia, several VMS prospects have been identified. The Alaskan VMS occurrences are in the Delta, Bonnifield and Trident Glacier districts.

Exploration during this period was not confined to the YTT but extended into rocks of the North American miogeocline that are coeval, and possibly correlative, with Devono-Mississippian strata of the YTT. This led to the discovery of additional resources at the Marg and Wolf VMS deposits. The Marg deposit (5 527 002 tonnes of 1.76% Cu, 2.46% Pb, 4.60% Zn, 62.7 g/t Ag and 1.0 g/t Au) occurs in the Selwyn Basin within a Devonian to Mississippian sequence of carbonaceous siliceous phyllite, quartz-muscovite and quartz-chlorite phyllite and massive quartzite. These strata also host the Jane prospect. The Wolf deposit (4.1 million tonnes of 6.2% Zn, 1.8% Pb and 84 g/t Ag) occurs in the Pelly-Cassiar Platform within the Devono-Mississippian Pelly Mountains volcanic belt and is hosted by felsic metavolcanic and associated metasedimentary rocks. Numerous other VMS prospects, including MM, occur throughout the length of this 80-km-long volcanic belt.

The newly defined VMS deposits are comparable in size to the average Canadian VMS deposit indicating the discoveries are significant. Mineralization in the YTT occurs in Late Devonian to Permian strata thus there are several prospective horizons and the potential for additional discoveries is significant.

RÉSUMÉ

La découverte en 1994 du gisement de sulfures massifs volcanogènes (SMV) Kudz Ze Kayah (KZK), suivie peu après par la découverte du gisement Wolverine, a mené à une période d'exploration intense au Yukon. Cette exploration a permis de découvrir de nouvelles minéralisations de SMV, incluant les gisements GP4F et Ice, d'augmenter les réserves du gisement Fyre Lake, et d'identifier de nombreuses zones de prospection.

Les gisements KZK, Wolverine, GP4F, Fyre Lake et Ice sont contenus dans le terrane Yukon-Tanana (TYT) dans le district du lac Finlayson au sud-est du Yukon. Le gisement Fyre Lake (8 200 000 de tonnes titrant 2,1 % de Cu et 0,73 g/t d'Au) se situe le plus bas dans l'échelle stratigraphique et se présente dans des métavolcanites mafiques faisant partie de la succession de Grass Lakes et datant du Dévonien au Mississippien. Les gisements KZK (13 000 000 de tonnes titrant 5,5 % de Zn, 1 % de Cu, 1,3 % de Pb, 125 g/t d'Ag et 1,2 g/t d'Au) et GP4F (1 500 000 tonnes titrant 6,4 % de Zn, 3,1 % de Pb, 0,1 % de Cu, 89,7 g/t d'Ag et 2,0 g/t d'Au) se retrouvent aussi au sein de la succession de Grass Lake, mais se présentent dans des métavolcanites felsiques susjacentes au gisement Fyre Lake. Le gisement Wolverine (6 237 000 tonnes titrant 12,66 % de Zn, 1,33 % de Cu, 1,55 % de Pb, 370,9 g/t d'Ag et 1,76 g/t d'Au) est encaissé dans des métavolcanites rhyolitiques du Carbonifère et des argilites carbonées de la succession de Wolverine. Le gisement Ice (4 561 863 tonnes titrant 1,48 % de Cu), le plus élevé dans l'échelle stratigraphique, est contenu dans des métavolcanites mafiques du Paléozoïque tardif et dans les roches métasédimentaires associées de la succession de Campbell Range.

Le TYT couvre une grande partie du Yukon et du centre est de l'Alaska ainsi que des parties de la Colombie-Britannique. En conséquence, en plus de la région du lac Finlayson, on trouve des minéralisations en SMV dans les régions de Dawson et Glenlyon, au Yukon, ainsi que dans la région et de Teslin-Rancheria du Yukon et parties avoisinantes de la Colombie-Britannique, de même que dans plusieurs régions de l'Alaska. La région de Dawson est adjacente au district du lac Finlayson riche en sulfures massifs, si l'on rétablit le décrochement dextre d'environ 425 km de la faille de Tintina. Dans cette région, les zones de prospection à la recherche de SMV sont contenues dans l'Assemblage de Nasina datant du Dévonien tardif au Mississippien moyen et dans le Schiste de Klondike datant du Permien. Dans la région de Glenlyon, la minéralisation en sulfures massifs et les horizons de chert ont été identifiés dans une ceinture de roches associées au TYT d'au moins 20 km de long. Plusieurs zones de prospection à la recherche de SMV se trouvent dans des roches associées au TYT dans la région de Teslin-Rancheria au Yukon et, au-delà de la limite provinciale, dans le nord de la Colombie-Britannique. En Alaska, les indices de SMV se retrouvent dans les districts de Delta, de Bonnifield et du glacier Trident.

Les activités d'exploration durant cette période n'étaient pas limitées au TYT. Les strates du miogéoclinal nord-américain contemporaines des strates du Dévonien-Mississippien du TYT, et qui seraient peut-être en corrélation avec elles, furent aussi l'objet de travaux d'exploration. Ces travaux ont permis la découverte de réserves additionnelles au gisements de SMV Marg et Wolf. Le gisement Marg (5 527 002 tonnes titrant 1,76 % de Cu, 2,46 % de Pb, 4,60 % de Zn, 62,7 g/t d'Ag et 1,0 g/t d'Au) est situé dans le bassin de Selwyn à l'intérieur d'une séquence de phyllades siliceuses carbonées du Dévonien au Mississippien précoce, de phyllades à muscovite et quartz et à chlorite et quartz, et de quartzite massif. Ces strates encaissent aussi la zone de prospection Jane. Le gisement Wolf (4,1 millions de tonnes titrant 6,2 % de Zn, 1,8 % de Pb et 84 g/t d'Ag) se trouve dans la plate-forme de Pelly-Cassiar, à l'intérieur de la zone volcanique des monts Pelly, datant du Dévonien au Mississippien, encaissé dans des métavolcanites felsiques et des roches métasédimentaires associées. De nombreux indices de SMV, dont l'indice MM, se retrouvent sur l'ensemble des 80 km de la zone volcanique des monts Pelly.

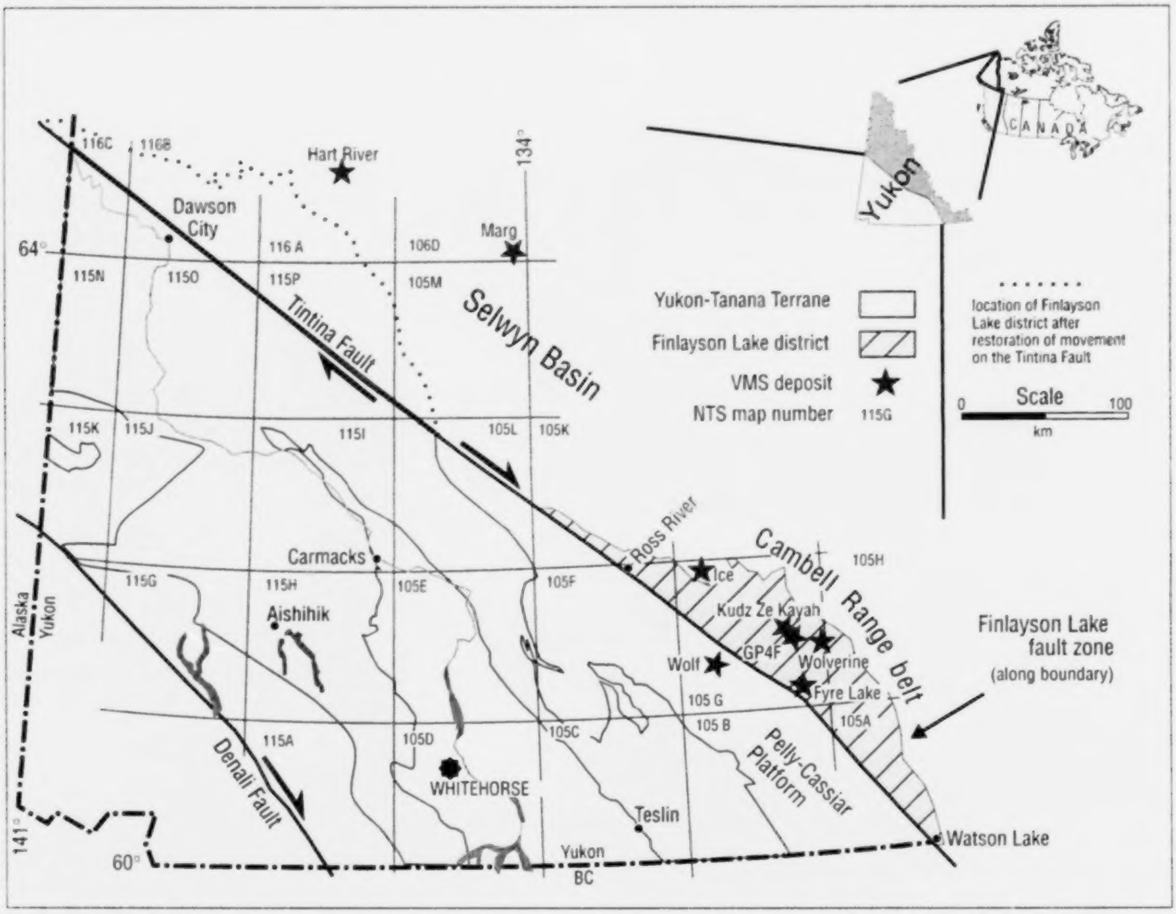
Le gisement Marg (5,527 millions de tonnes titrant 1,76 % de Cu, 2,46 % de Pb, 4,60 % de Zn, 62,7 g/t d'Ag et 1,0 g/t d'Au) est situé dans le bassin de Selwyn à l'intérieur d'une séquence de phyllites siliceuses carbonées probablement du Mississippien précoce, de phyllites à muscovite quartzique et à chlorite quartzique, et de quartzite massif.

La zone volcanique des monts Pelly, datant du Dévonien au Mississippien, est située à l'est du district du lac Finlayson dans la plate-forme de Pelly-Cassiar et il y a minéralisation en SMV sur l'ensemble des 80 km de la zone volcanique. Il y a des strates contemporaines de cette zone dans le bassin de Selwyn et elles renferment la zone de prospection de Jane en plus du gisement Marg.

INTRODUCTION

Volcanic-associated massive sulphide (VMS) deposits are accumulations of sulphide minerals that precipitate from hydrothermal fluids at, or below the seafloor in a wide range of geological settings (cf. Franklin et al., 1981, Barrie and Hannington, 1997). They occur within volcano-sedimentary stratigraphic successions, and are commonly coeval and spatially associated with volcanic rocks. As a class, they represent a significant source of the world's copper (Cu), zinc (Zn), lead (Pb), gold (Au) and silver (Ag), with cobalt (Co), tin (Sn), barium (Ba), selenium (Se), manganese (Mn), cadmium (Cd), indium (In), bismuth (Bi), tellurium (Te), gallium (Ga) and germanium (Ge) as co- or by-products (Barrie and Hannington, 1997).

Until recently, VMS deposits did not form a significant part of the Yukon's known mineral inventory. Prior to 1994, the only significant VMS deposits known in the Yukon were Hart River and Marg (Fig. 1). In the mid 1990s this changed significantly with the discovery of high-grade mineralization at the Kudz Ze Kayah (KZK) and Wolverine massive sulphide deposits in the Finlayson Lake area of southeastern Yukon (Fig. 1). The discovery of



CANADA
Yukon
116C
116B
Hart River
134°
Dawson City
64°
116 A
106D
Marg
115N
115O
115P
105M
Tintina Fault
Selwyn Basin
Yukon-Tanana Terrane
Finlayson Lake district
VMS deposit
NTS map number
115G
location of Finlayson Lake district after restoration of movement on the Tintina Fault
Scale
0
100
km
115K
115J
115I
105L
105K
Ross River
Cambell Range belt
105H
Carmacks
115G
115H
105E
105F
Ice
Kudz Ze Kayah
Aishihik
GP4F
Wolverine
Finlayson Lake fault zone (along boundary)
Wolf
Fyre Lake
105 G
105 B
105A
Alaska
Yukon
115A
105D
105C
Pelly-Cassiar Platform
Denali Fault
WHITEHORSE
Teslin
141°
60°
Yukon
BC
Watson Lake

Figure 1. Location of significant VMS deposits in the Yukon. Hart River and Marg were discovered prior to 1994 and those in the Finlayson Lake area were discovered subsequently. Also shown are the locations of the Yukon-Tanana Terrane (YTT), the Finlayson Lake district, and the approximate location of the Finlayson Lake area of the YTT after restoration of movement along the Tintina Fault.

these new deposits, which are hosted in the Yukon-Tanana Terrane (YTT), triggered a staking rush - the like of which had not been seen since the Klondike gold rush. The Finlayson rush was followed by intense exploration activity in the YTT and in coeval, and possibly correlative, strata that underlie parts of the Pelly-Cassiar Platform (PCP) and Selwyn Basin. This increased exploration activity led to additional discoveries including (Fig. 1) the Ice and GP4F deposits and significant new mineralization at Fyre Lake in the YTT, the Wolf deposit in the PCP and the Marg deposit in the Selwyn Basin, plus numerous occurrences, many of which are not yet fully evaluated.

The size and grade of the recently discovered VMS deposits in the Yukon compares favourably to the Canadian average for Cu-Zn and Zn-Pb-Cu type VMS deposits indicating that they are significant and that the Finlayson Lake district is an important emerging VMS district (Table 1; see Franklin (1996) for information on grade and tonnage and classification of VMS deposits).

This report focuses on the results of a study of the above-mentioned deposits and their host strata. Analytical results and petrographic descriptions are presented in the appendices. The report summarizes the geology of the YTT and presents descriptions of mineral deposits and occurrences hosted by this terrane in the Finlayson Lake district and the Dawson and Teslin-Rancheria areas of the Yukon (Figs. 1, 2). VMS mineralization hosted by YTT strata in Alaska (Delta, Trident Glacier and Bonnifield districts, and the Juneau and Ketchikan areas) and northern British Columbia is discussed briefly (Fig. 2). The report also includes descriptions of VMS mineralization in coeval strata that underlie the PCP and Selwyn Basin in the Yukon.

Table 1. *Recently discovered (or expanded) Cu-Zn and Zn-Pb-Cu type VMS deposits in the Yukon compared to the Canadian average. References are: Canadian average, Franklin (1996); Fyre Lake, Columbia Gold, pers. comm. (1998); Ice, Expatriate Resources Ltd. (1998); Kudz Ze Kayah (ABM), (Schultze, 1996a); Kudz Ze Kayah (GP4F), and Wolverine, Expatriate Resources Ltd. (1999a); Marg, Franzen (1997); and Wolf, Gibson et al. (1999).*

DEPOSIT NAME	SIZE MT	Cu %	Zn %	Pb %	Ag g/t	Au g/t
Cu-Zn TYPE						
Fyre Lake (Kona Deposit)	8.2	2.1				0.73
Ice	4.56	1.48	minor		minor	minor
Canadian average	5.3	1.95	4.23	0.09	19.0	0.8
Zn-Pb-Cu TYPE						
Kudz Ze Kayah (ABM)	13	1.0	5.5	1.3	125	1.2
Kudz Ze Kayah (GP4F)	1.5	0.1	6.4	3.1	90	2.0
Wolverine	6.237	1.33	12.66	1.55	371	1.76
Marg	5.5	1.76	4.5	2.5	86	0.9
Wolf	4.1		6.2	1.8	84	
Canadian average	5.6	1.23	3.6	1.46	79.0	2.0

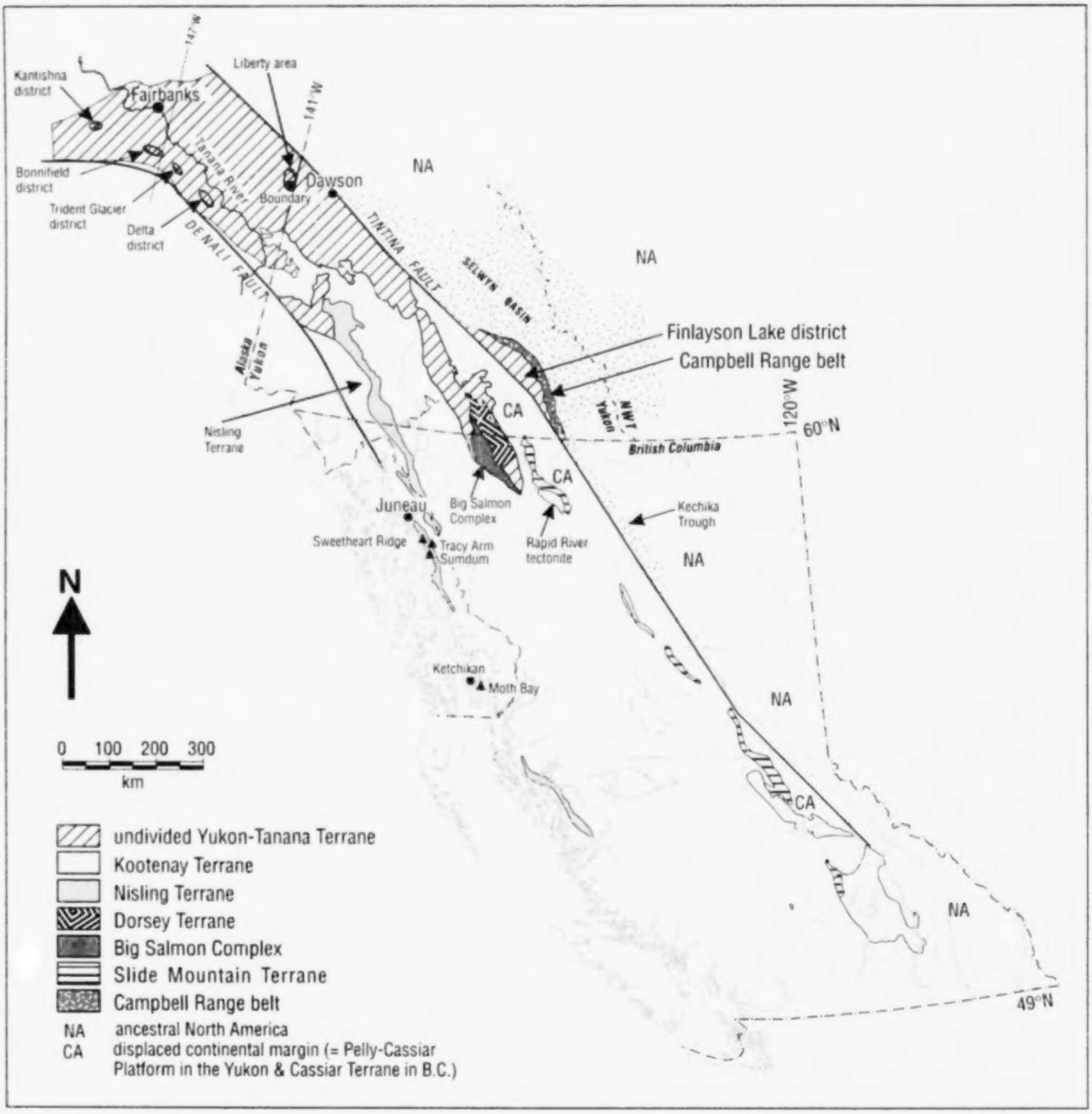

147°W
Kantishna district
Fairbanks
Liberty area
141°W
Bonnifield district
Trident Glacier district
Delta district
Tanana River
Boundary
Dawson
NA
DENALI FAULT
TINTINA FAULT
SELWYN BASIN
NA
Finlayson Lake district
Campbell Range belt
Alaska
Yukon
Nisling Terrane
CA
NWT
Yukon
120°W
60°N
British Columbia
CA
Juneau
Big Salmon Complex
Rapid River tectonite
Kechika Trough
Sweetheart Ridge
Tracy Arm
Sumdum
NA
N
Ketchikan
Moth Bay
NA
0 100 200 300
km
CA
NA
49°N
▨ undivided Yukon-Tanana Terrane
☐ Kootenay Terrane
☐ Nisling Terrane
▨ Dorsey Terrane
■ Big Salmon Complex
☰ Slide Mountain Terrane
▩ Campbell Range belt
NA ancestral North America
CA displaced continental margin (= Pelly-Cassiar Platform in the Yukon & Cassiar Terrane in B.C.)

Figure 2. *Distribution of the Yukon-Tanana Terrane, Kootenay, Nisling, Dorsey, and Slide Mountain terranes, Big Salmon Complex and Campbell Range belt. Also shown are the locations of Selwyn Basin, Cassiar terrane (CA) and Ancestral North America (NA). Modified from a figure by Joanne Nelson (written communication, 1997).*

YUKON-TANANA TERRANE

SUMMARY OF GEOLOGY

Terminology used to refer to the Yukon-Tanana Terrane (YTT) varies between areas and workers, and can be confusing (see Mortensen 1992a, for a review of nomenclature). Mortensen (1992a) cautions that it is important to keep in mind the size of the YTT. It covers a large area, and therefore, substantial variations in lithologic assemblages, metamorphic grade and the amount of strain should be expected. Lithological correlations based on metamorphic grade, the presence or nature of deformation fabrics, metamorphic cooling ages and/or structural position must be undertaken with caution. The following summary focuses on rocks in the YTT that are known to host VMS deposits in the Yukon and Alaska, and are **pre-mid-Mesozoic** in age.

The YTT underlies much of the Yukon, east-central Alaska and parts of British Columbia (Fig. 2). It is a large terrane that lies between the ancestral North American continental margin to the east and exotic terranes to the west (Gabrielse and Yorath, 1991; Mortensen, 1992a). The YTT is made up primarily of poorly exposed, polydeformed, metaigneous and metasedimentary rocks. Pre-mid-Mesozoic rocks (Devonian to Permian) of the YTT consist mainly of pelitic to quartzo-feldspathic metasedimentary schist and gneiss with minor marble, and deformed mafic to felsic metavolcanic and metaplutonic rocks (cf. Mortensen, 1992a). Most units within YTT display a penetrative ductile deformation fabric and have been affected by regional-scale thrust faulting (Mortensen and Jilson, 1985; Mortensen 1992a; Dusel-Bacon et al., 1998).

There is increasing evidence that the various areas mapped within the Yukon as YTT are closely related to each other and to the Nisling Terrane in southwestern Yukon (Fig. 2; see Mortensen, 1992a, for complete descriptions of these similarities). Mortensen (1992a) argues that the YTT, the Dorsey Terrane, and the Nisling Terrane (made up of the Nasina and Nisling Assemblages) represent portions of a single terrane and that lithological differences between components reflect lateral facies variations and/or present level of exposure and consequent variations in metamorphic grade. In the Yukon, the older (pre-mid-Paleozoic) portion of this composite terrane is considered to be the Nisling Assemblage, which is thought to represent a passive continental margin setting (cf. Mortensen, 1992a). The Nisling Assemblage is overlain by the Nasina Assemblage, a dominantly mid-Paleozoic sequence of metasedimentary rocks with lesser metavolcanic and metaplutonic rocks. The Nasina Assemblage likely represents a continental magmatic arc, presumably built on Nisling Assemblage. The youngest components of the composite terrane include Pennsylvanian and Permian clastic metasedimentary rocks and marble, plus locally abundant metaigneous rocks, that were deposited on the Nasina Assemblage (Mortensen, 1992a). Rocks of the youngest component are rarely preserved and are known locally as the Klondike Schist.

Following are descriptions of geology and mineralization for areas of the YTT that host VMS deposits and occurrences. YTT descriptions are divided into the recently discovered Finlayson Lake district, and correlative strata in the Dawson area, Alaska and northern British Columbia (Fig. 2). These are followed by descriptions of areas underlain by coeval strata in the Pelly-Cassiar Platform and Selwyn Basin.

The most recent compilation of bedrock geology and till geochemistry of the northern Finlayson Lake map area is now available on CD-Rom (Bond et al., 2002), however information from that study is not included within this report. Geoscientific studies of the Yukon-Tanana Terrane are part of an ongoing NATMAP project by members of the Yukon Geology Program and the Geological Survey of Canada. For the most up-to-date information the reader is recommended to view the latest literature by J.D. Bond, M. Colpron, S.P. Gordey, D.C. Murphy, A. Plouffe, C.F. Roots or J. Ryan.

FINLAYSON LAKE DISTRICT

GEOLOGY

The YTT in the Finlayson Lake area is lozenge-shaped, approximately 300 km long, and at most, 50 km wide (Fig. 1). It is juxtaposed against Proterozoic and Paleozoic miogeoclinal strata of the ancestral North American continental margin along the Tintina fault zone to the southwest, and along the Finlayson Lake fault zone to the northeast (Figs. 1, 2). The main part of the YTT, which underlies most of west-central Yukon, is contiguous with the Finlayson Lake portion after restoration of approximately 425 km of Late Cretaceous right-lateral strike-slip movement on the Tintina Fault (Fig. 1; Roddick, 1967; Tempelman-Kluit, 1976; Mortensen, 1983; Gabrielse, 1991). The nature of the Finlayson Lake fault zone remains uncertain as it has been variably interpreted as a transpressive suture (Mortensen and Jilson, 1985) and a thrust fault zone (Plint and Gordon, 1997).

Regional mapping in the Finlayson Lake area (NTS 105G) was carried out by Wheeler et al. (1960a), Tempelman-Kluit (1977a), and Mortensen and Jilson (1985) at scales of 1 inch to 4 miles or 1:250 000. The following sequences were recognized in the Finlayson Lake area by Mortensen and Jilson (1985; Fig. 3a):

1. a lower unit consisting mainly of quartzo-feldspathic metasedimentary rocks and minor pelitic schist with marble, calcsilicate and calcareous schist bands occurring near the top;
2. a middle unit of carbonaceous phyllite, schist and quartzite with rare marble and pebble conglomerate, all interlayered with mafic and felsic metavolcanic rocks that yield Late Devonian to Mississippian crystallization ages; and
3. an upper unit of marble and quartzite that is at least in part Early Pennsylvanian to Early Permian (conodont ages Tempelman-Kluit, 1979; M. Orchard, pers. comm., 1984, *in:* Murphy and Piercey, 1999a).

Upper Paleozoic mafic volcanic and intercalated sedimentary rocks of the Campbell Range belt (CRB) overlie the above sequences in the Finlayson Lake area (cf. Murphy and Piercey, 1999a,b). In early work, the CRB was interpreted as part of the Anvil Allochthon (Tempelman-Kluit, 1977a, b) or the Slide Mountain Terrane (Mortensen and Jilson, 1985; Plint and Gordon, 1996, 1997) in thrust contact with the underlying YTT. New mapping (Schultze and Hall, 1997; Murphy and Piercey, 1999a) indicates that rocks of the CRB sit stratigraphically on strata of the YTT. Depositional ages for rocks of the CRB are inferred to be Pennsylvanian to Permian or younger based on lithologic similarities to other rocks types in the region (Mortensen, 1992b) and sparse age data. Two specimens collected east of the Wolverine deposit (Plint and Gordon, 1997) yielded Mississippian-Permian fossil ages.

Figure 4 (in pocket), at 1:100 000 scale, summarizes recent mapping at 1:50 000 scale including Grass Lakes (105G/8), Wolverine Lake (105G/7), McEvoy Creek (105G/9), Waters Creek (105G/1) and Fire Lake (105G/2) map areas. This 1:100 000 scale map, after Murphy and Piercey (1999b,), revises the units of Mortensen and Jilson (Fig. 3a: 1985) and replaces numbered designations (Fig. 3b: cf. Murphy and Piercey, 1998) with named designations (Fig. 3c: Murphy and Piercey, 1999b, 2000). Complete information can be found in Murphy and Timmerman (1997a,b), Murphy (1997a, 1998, 2001), Hunt and Murphy (1998), Murphy and Piercey (1999a,b,c, 2000), Piercey and Murphy (2000) and Piercey et al. (2001). Figures 3c and 4 are summarized below.

Figures 3c and 4 define the detailed geology of the Finlayson Lake area. The deformed and metamorphosed volcanic, intrusive and sedimentary rocks in the Finlayson Lake area have been divided by Murphy and Piercey (1999b,c) into three stratigraphic successions, the Grass Lakes, Wolverine and Campbell Range successions (Figs. 3c, 4). The Devonian to Mississippian Grass Lakes succession is stratigraphically lowest and is made up, in part, of a basal unit (units Dq, Dqc, Dm, Df/Unit 1) of non-carbonaceous, metasedimentary rocks and marble. The basal unit is overlain by rocks of the ~ 365-360 Ma (Piercey et al., 2001) Fire Lake metavolcanic unit (unit DMF/Unit 2) made up of mafic metavolcanic and metaintrusive rocks, and lesser felsic metavolcanic rocks, carbonaceous phyllite and quartzite, and marble. The Fire Lake metavolcanic unit is stratigraphically overlain by the ~360 Ma (ibid.) Kudz Ze Kayah felsic metavolcanic unit (units MK, q, cp/Unit 3). This unit consists dominantly of felsic metavolcanic and carbonaceous metasedimentary rocks with lesser mafic metavolcanic and metaintrusve rocks, and felsic metaintrusive rocks. The remainder of the Grass Lakes succession, overlying the Kudz Ze Kayah felsic metavolcanic unit, is made up of feldspar-quartz-pebble conglomerate, quartzite, biotite-chlorite schist and carbonaceous phyllite and quartzite (units Mcg, Mq, Mm, Mcp/Unit 4).

The Carboniferous Wolverine Lake succession (Figs. 3c, 4) unconformably overlies the Grass Lakes succession. The basal unit of the Wolverine Lake succession is made up of quartz-feldspar-pebble metaconglomerate and metasandstone (unit CWcl/Unit 5). Overlying the basal unit is carbonaceous phyllite and quartz metasandstone (unit CWcp). This is, in turn, overlain by a package of ~ 345 Ma (ibid.) rhyolitic metavolcanic rocks made up of flows, volcaniclastic and epiclastic rocks (unit CWf); locally, this unit is made up of feldspar ± quartz porphyritic rhyolitic metaintrusive rocks (unit CWq). The top of the Wolverine Lake succession is made up of rhyolitic metavolcaniclastic and metaepiclastic rocks, rhyolitic metaintrusive rocks and metavolcanic flow rocks,

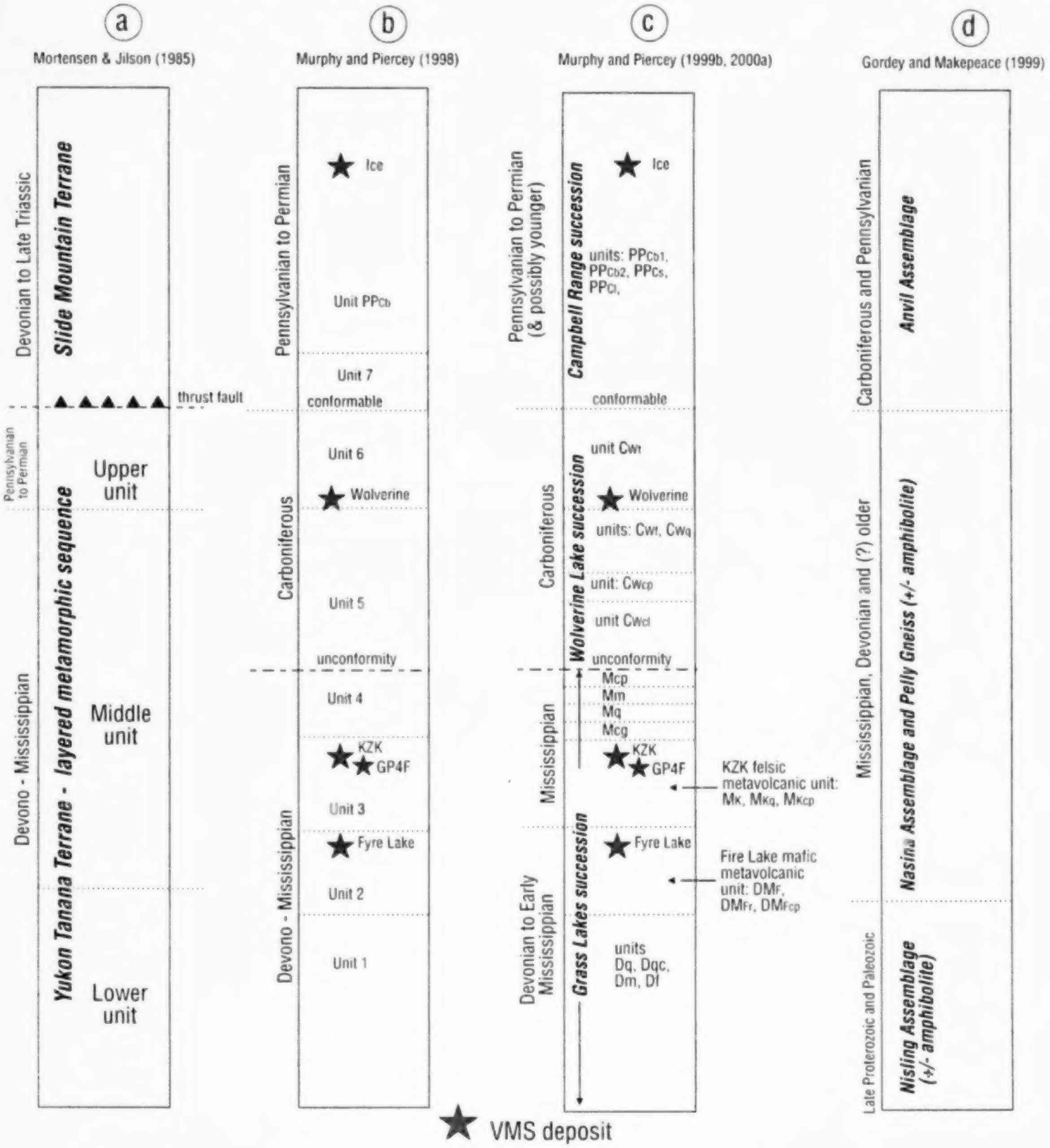

a
Mortensen & Jilson (1985)
Devonian to Late Triassic
Slide Mountain Terrane
thrust fault
Pennsylvanian to Permian
Upper unit
Devono - Mississippian
Yukon Tanana Terrane - layered metamorphic sequence
Middle unit
Lower unit
b
Murphy and Piercey (1998)
Pennsylvanian to Permian
Ice
Unit PPcb
Unit 7
conformable
Unit 6
Wolverine
Carboniferous
Unit 5
unconformity
Unit 4
KZK
GP4F
Unit 3
Fyre Lake
Devono - Mississippian
Unit 2
Unit 1
c
Murphy and Piercey (1999b, 2000a)
Pennsylvanian to Permian (& possibly younger)
Campbell Range succession
Ice
units: PPcb1, PPcb2, PPcs, PPcl,
conformable
Carboniferous
Wolverine Lake succession
unit Cwr
Wolverine
units: Cwr, Cwq
unit: Cwcp
unit Cwcl
unconformity
Mississippian
Mcp
Mm
Mq
Mcg
KZK
GP4F
KZK felsic metavolcanic unit: Mk, Mkq, Mkcp
Devonian to Early Mississippian
Grass Lakes succession
Fyre Lake
Fire Lake mafic metavolcanic unit: DMF, DMFr, DMFcp
units Dq, Dqc, Dm, Df
d
Gordey and Makepeace (1999)
Carboniferous and Pennsylvanian
Anvil Assemblage
Mississippian, Devonian and (?) older
Nasina Assemblage and Pelly Gneiss (+/- amphibolite)
Late Proterozoic and Paleozoic
Nisling Assemblage (+/- amphibolite)
VMS deposit

Figure 3. Evolution of nomenclature for metasedimentary and metavolcanic rocks in the Finlayson Lake area. Regional units (1:250 000 scale) identified by Mortensen and Jilson (Fig. 3a: 1985) were refined by Murphy and Piercey (1998) during more detailed mapping (1:50 000 scale) into numbered units (Fig. 3b) and then named units (Fig. 3c). Additional detail, provided in Murphy and Piercey (1999b, 2000a), is used in Figure 4. A regional digital compilation (1:1 000 000 scale) by Gordey and Makepeace (Fig. 3d: 1999) is used in Figure 5.

and carbonaceous phyllite (unit CWt/Unit 6). Iron formation horizons occur locally within this unit.

The Wolverine Lake succession (Figs. 3c, 4) is overlain by the Pennsylvanian to Permian (Plint and Gordon, 1997), and possibly younger (Orchard in Appendix VI-3) Campbell Range succession. The Campbell Range succession is made up of massive to pillowed and brecciated basalt, maroon and green chert, gabbro and diabase separated by sedimentary rocks that include carbonaceous argillite, sandstone and quartz grit, diamictite, varicoloured chert and argillite, chert-pebble conglomerate and limestone (Murphy and Piercey, 1999a,b,c).

The older successions are intruded by (Fig. 4; ibid.) Devonian to Mississippian quartz-porphyritic metagranite (unit DMg), ultramafic rocks (units DMum, DMgo) and hornblende-biotite metadiorite (unit DMd), the granitic to granodioritic Mississippian Simpson Range Plutonic Suite (units MSgd, gs, g) and the granitic to monzonitic Mississippian Grass Lakes metaplutonic suite (unit MGg). Other intrusive rocks in the Finlayson Lake area include Pennsylvanian to Permian ultramafic rocks (unit ℙPum) and leucogabbro (unit ℙPlg), Permian granitic dykes (Pg) and Cretaceous biotite-muscovite granite (unit Kg).

Correlation of individual rock units between areas is difficult. In any volcanic pile individual lithologies tend to be highly variable with respect to thickness and aerial distribution due to irregular paleodepositional surfaces, proximity to volcanic vents and dynamic to catastrophic local tectonics. In addition, the above successions are deformed and metamorphosed. However, the degree of strain is heterogeneous and locally primary textures are preserved. For example, spherulites/amygdules are preserved in mid-Paleozoic rhyolitic rocks just west of Kudz Ze Kayah, and relict quartz and feldspar phenocrysts are visible in Mississippian intrusive rocks in the Wolverine Lake area.

Figure 5 is part of a Yukon-wide geological compilation map (1:1 000 000 scale) by Gordey and Makepeace (1999; Fig. 3d) that incorporated the geology of Figures 3c and 4. They correlated the YTT in the Finlayson Lake area mainly with the Nisling and Nasina assemblages and the Pelly Gneiss; they included the CRB as part of the Anvil Assemblage.

Mineralization

The above stratigraphy contains at least four horizons that host VMS deposits (Figs. 3b,c; synthesized in Murphy and Piercey, 1999a; and partly summarized in Hunt, 1997, 1998a,b, 1999c). The copper-cobalt-gold-bearing Fyre Lake deposit is hosted by the Fire Lake mafic metavolcanic unit. It lies close to the contact with overlying carbonaceous phyllite of the Kudz Ze Kayah felsic metavolcanic unit that hosts the zinc-lead-precious metal-rich GP4F deposit and the zinc-lead-copper and precious metal-rich ABM (Kudz Ze Kayah) deposit. GP4F occurs slightly lower in the stratigraphy than Kudz Ze Kayah (T. Tucker, pers. comm., October, 2000). The zinc-lead-copper and precious-metal-rich Wolverine deposit is hosted by felsic metavolcanic rocks and associated metasedimentary rocks of the Wolverine Lake succession. The copper-cobalt-gold-bearing Ice deposit is hosted by brecciated pillowed mafic volcanic rocks at the northwest end of the CRB. Gossanous pyritic felsic metavolcanic rocks of the basal unit of the Grass Lakes succession may constitute a fifth mineralized horizon (Murphy, 1998).

PRELIMINARY LITHOGEOCHEMISTRY

Specimens were collected for lithogeochemical analysis in an attempt to define the signature of ore-bearing strata and to provide information on the tectonic setting of the mineral deposits and their host metavolcanic rocks. Specimens were analysed for major, trace and rare-earth elements (REE) at Activation Laboratories Limited in Ancaster, Ontario. Major elements were analysed on fused discs by X-ray fluorescence; trace elements and REE were analysed by research-quality inductively coupled plasma mass spectrometry. Results are in Appendix VI-2.

Results for the Fire Lake area have been analysed by Sebert (initial results are in Sebert and Hunt, 1999) and the remaining specimens for the Finlayson Lake area are being analysed as part of an ongoing project by Piercey as part of a Ph.D. thesis at The University of British Columbia (initial results are reported in Piercey et al., 1999). Results from these studies are summarized below.

- **Fire Lake mafic metavolcanic unit (unit DMF/Unit 2)**

The Fire Lake mafic metavolcanic unit (unit DMF/Unit 2 of Fig. 3b) which hosts the Fyre Lake deposit, was subdivided by Piercey et al. (1999) into three geochemical suites (2a, 2b and 2c) based on trace and major element contents (Fig. 6a, b). Suite 2a ranges from subalkalic basalt

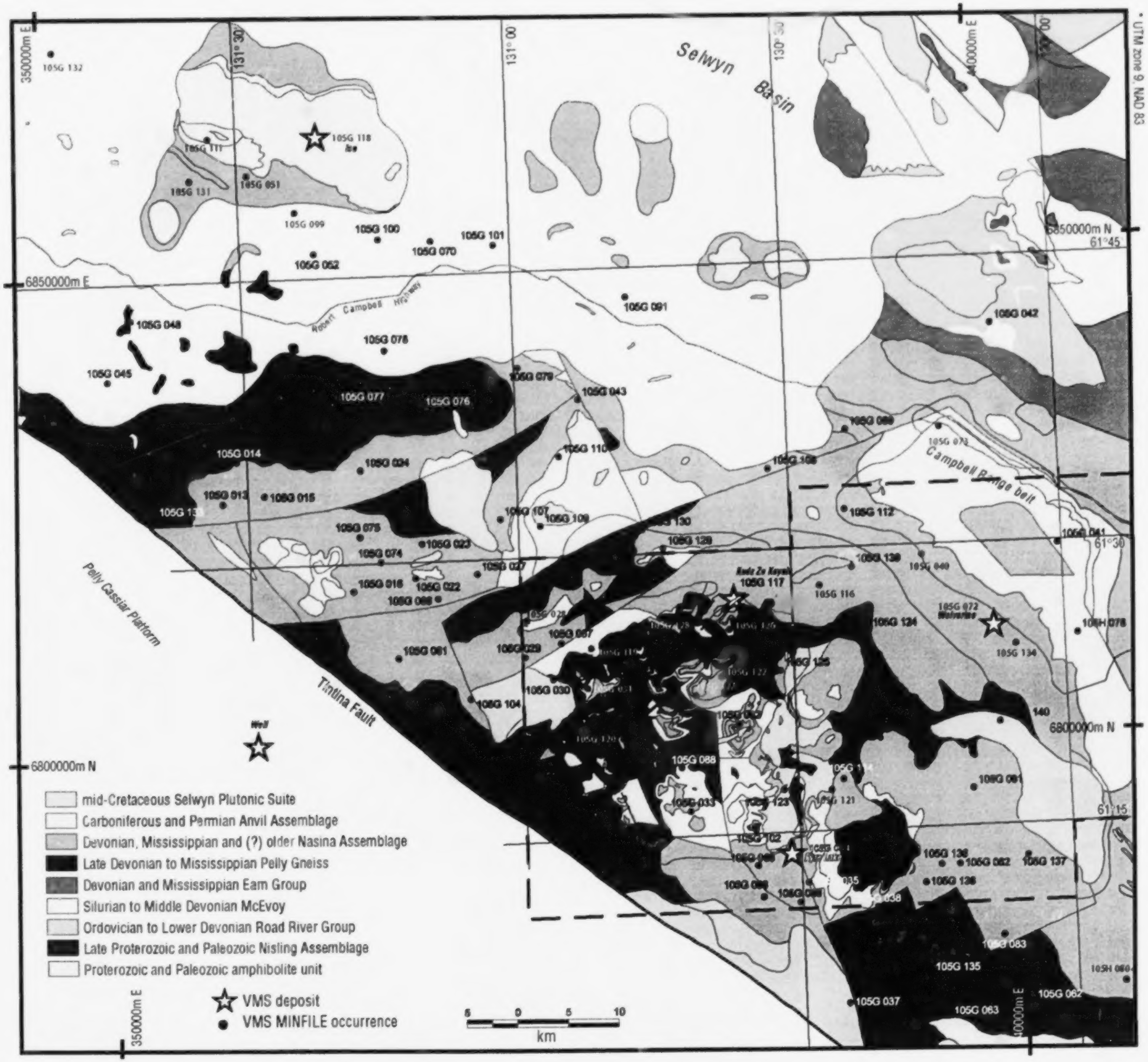

* UTM zone 9, NAD 83
350000m E
400000m E
6850000m N
6800000m N
6850000m E
6800000m N
61°45
61°30
61°15
131°30'
131°00
130°30
130°00
Selwyn Basin
Campbell Range belt
Robert Campbell Highway
Pelly Cassiar Platform
Tintina Fault
Ice
105G 118
Wolverine
105G 072
Kudz Ze Kayah
105G 117
Wolf
105G 132
105G 111
105G 131
105G 051
105G 099
105G 100
105G 070
105G 101
105G 052
105G 091
105G 042
105G 048
105G 078
105G 045
105G 079
105G 043
105G 077
105G 076
105G 089
105G 014
105G 034
105G 110
105G 108
105G 013
105G 015
105G 107
105G 109
105G 112
105G 130
105G 075
105G 023
105G 129
105G 074
105G 027
105G 139
105G 040
105G 041
105G 016
105G 022
105G 088
105G 116
105G 124
105H 078
105G 134
105G 087
105G 029
105G 081
105G 125
105G 030
105G 104
140
105G 088
105G 091
105G 033
105G 123
105G 121
105G 102
105G 136
105G 082
105G 137
105G 138
105G 083
105G 135
105H 080
105G 037
105G 063
105G 062
mid-Cretaceous Selwyn Plutonic Suite
Carboniferous and Permian Anvil Assemblage
Devonian, Mississippian and (?) older Nasina Assemblage
Late Devonian to Mississippian Pelly Gneiss
Devonian and Mississippian Earn Group
Silurian to Middle Devonian McEvoy
Ordovician to Lower Devonian Road River Group
Late Proterozoic and Paleozoic Nisling Assemblage
Proterozoic and Paleozoic amphibolite unit
☆ VMS deposit
● VMS MINFILE occurrence
5 0 5 10
km

Figure 5. VMS deposits and mineral occurrences of the Finlayson Lake area. Geology is from Gordey and Makepeace (1999). Dashed line outlines the area shown in Figure 4 from Murphy and Piercey (1999b). The locations of VMS deposits and occurrences are from Yukon MINFILE (2001).

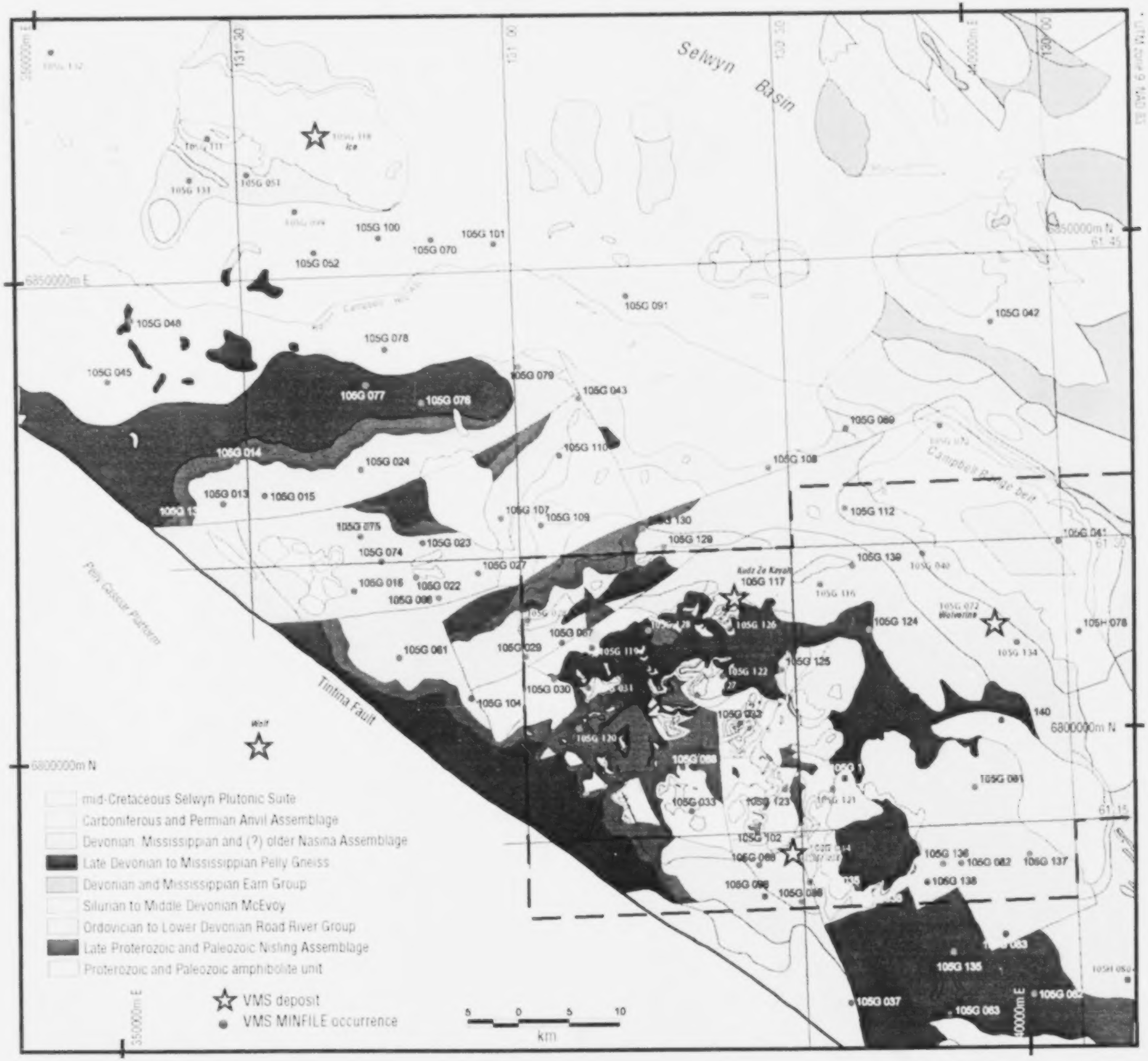

UTM zone 9, NAD 83
Selwyn Basin
Campbell Range belt
Pelly Cassiar Platform
Tintina Fault
131°30
131°00
130°30
130°00
6850000m E
6850000m N
6800000m N
350000m E
40000m E
61°45
61°30
61°15
Ice
Kudz Ze Kayah
Wolverine
Wolf
105G 117
105G 045
105G 048
105G 077
105G 076
105G 078
105G 079
105G 043
105G 091
105G 042
105G 089
105G 108
105G 112
105G 041
105H 078
105G 124
105G 139
105G 014
105G 013
105G 015
105G 024
105G 075
105G 074
105G 023
105G 016
105G 022
105G 027
105G 081
105G 104
105G 030
105G 029
105G 087
105G 107
105G 109
105G 110
105G 130
105G 129
105G 100
105G 070
105G 101
105G 052
105G 051
105G 131
105G 126
105G 122
105G 125
105G 120
105G 033
105G 123
105G 102
105G 136
105G 082
105G 137
105G 138
105G 135
105G 037
105G 063
105G 062
105G 061
140
mid-Cretaceous Selwyn Plutonic Suite
Carboniferous and Permian Anvil Assemblage
Devonian, Mississippian and (?) older Nasina Assemblage
Late Devonian to Mississippian Pelly Gneiss
Devonian and Mississippian Earn Group
Silurian to Middle Devonian McEvoy
Ordovician to Lower Devonian Road River Group
Late Proterozoic and Paleozoic Nisling Assemblage
Proterozoic and Paleozoic amphibolite unit
☆ VMS deposit
● VMS MINFILE occurrence
5 0 5 10
km

Figure 5. VMS deposits and mineral occurrences of the Finlayson Lake area. Geology is from Gordey and Makepeace (1999). Dashed line outlines the area shown in Figure 4 from Murphy and Piercey (1999b). The locations of VMS deposits and occurrences are from Yukon MINFILE (2001).

to andesite and has a boninitic to low-Ti tholeiite affinity based on its low TiO_2, high field-strength element (HFSE)[1], and total rare-earth elements (REE)[2] contents; irregularly high transition-metals content (Ni, Cr)[3], magnesium numbers[4]; andesitic levels of SiO_2; and dish-shaped REE profile (see Kona Cirque specimens in Fig. 11c, d for similar REE profile; Sebert and Hunt, 1999; Piercey et al., 1999; Sebert et al., in prep). Suite 2b has transitional subalkalic basalt/andesite affinities, is enriched in light rare earth elements (LREE)[5] and has high Ti and HFSE contents consistent with rocks from enriched source regions transitional between tholeiitic and alkaline oceanic island basalts (OIB; Piercey et al., 1999). Suite 2c is made up of basaltic andesite and has chemical affinities intermediate between those of suites 2a and 2b, with normal mid-ocean ridge basalt (N-MORB) magmatism indicated by the moderate Ti content, LREE depletion and moderate HFSE and transitional element contents (Piercey et al., 1999).

The Fyre Lake deposit is hosted by boninitic rocks of suite 2a (Sebert and Hunt, 1999; Piercey et al., 1999; Sebert et al., in prep). Piercey et al. (1999) suggest that these rocks host VMS mineralization in preference to those of suites 2b and c due to the required high heat flow and extensional stress regime associated with the formation of boninitic rocks, which generally occur in forearc and/or back-arc settings (Crawford et al., 1989). An extensional stress regime could potentially provide the needed ground preparation for the percolation of hydrothermal fluids with circulation driven by high heat flow.

• Kudz Ze Kayah felsic metavolcanic unit (unit MK/Unit 3)

The Kudz Ze Kayah felsic metavolcanic unit (unit MK/Unit 3 of Fig. 3b) hosts the mineralization at Kudz Ze Kayah. This unit was subdivided by Piercey et al. (1999) into two geochemical suites (3a & 3b) with broadly alkalic arc signatures, based on trace and major element contents (Fig. 6c, d, e). Data for specimens from the Mississippian Simpson Range Plutonic Suite (SRPS; Murphy and Piercey, 1999b) are also presented here. Unit MK/Unit 3 metavolcanic rocks and those of the SRPS have broadly dacitic to rhyolitic compositions with some specimens exhibiting more alkaline trachyandesite to trachyte compositions (Fig. 6a; Piercey et al., 1999). Suite 3a is characterized by high SiO_2 and K_2O, low Na_2O contents and a strong negative Eu anomaly (Fig. 6e). Suite 3b has higher Na_2O and lower K_2O contents than suite 3a and a moderate negative Eu anomaly (Fig. 6e).

The chemical characteristics of suite 3a (low Eu content, slight LREE enrichment and low Zr/Y ratio: 2.54-12.60) indicate it formed in an extensional setting (Fig. 6d), likely at shallow crustal levels, and may be associated with subvolcanic intrusions (Piercey et al., 1999). This is based on comparisons with other areas (cf. Campbell et al., 1981; Galley, 1996). An extensional environment and associated subvolcanic intrusions could have provided the required ground preparation and heat source considered necessary for the formation of related VMS deposits (cf. Galley, 1996; Lentz, 1998). Suite 3a is therefore considered by Piercey et al. (1999) to be the most prospective suite in unit MK/Unit 3.

• Campbell Range belt

Mafic metavolcanic rocks of the Campbell Range belt (CRB) were subdivided by Piercey et al. (1999) into two geochemical suites (CRB1 and CRB2) based on trace element chemistry. Note: Suite CRB3, reported in Piercey et al. (1999), mistakenly included results from another source outside the CRB and is disregarded. CRB metavolcanic rocks are basaltic-andesitic to subalkaline basalts in composition (Fig. 6f) with moderate Ti/V ratios consistent with eruption in an ocean floor and/or back-arc/marginal basin setting (Fig. 6g; Piercey et al., 1999; Plint and Gordon, 1997). Suite CRB1 has geochemical characteristics consistent with enriched mid-ocean ridge basalts (E-MORB), and suite CRB2 is depleted in LREE and has characteristics consistent with N-MORB parentage (Fig. 6h; Piercey et al., 1999).

The chemistry of suite CRB2 is consistent with its formation from a depleted mantle source. The LREE and low field-strength element (LFSE)[6] enrichment in suite CRB1 indicates increased plume-(OIB-like) type mantle involvement in its genesis (Piercey et al., 1999). Piercey et al. (1999) suggest that CRB1 and CRB2 are associated with spreading centres and thus with high heat flow. They are, therefore, both considered to be prospective host rocks for VMS mineralization. The Ice deposit is hosted by CRB2 and the Money occurrence is hosted by CRB1.

[1] HFSE = Zr, Hf, Nb, Ta, Ti, P (Jenner, 1996)

[2] REE = La to Lu (Jenner, 1996)

[3] transition elements = Cr, Ni, Sc, V, Co, Cu, Zn (Jenner, 1996)

[4] magnesium number = [Mg/(Mg+Fe)]x100

[5] LREE = La, Ce, Pr, Nd (Jenner, 1996)

[6] LFSE = Cs, Rb, K, Ba, Sr, Th, U, Pb (Jenner, 1996)

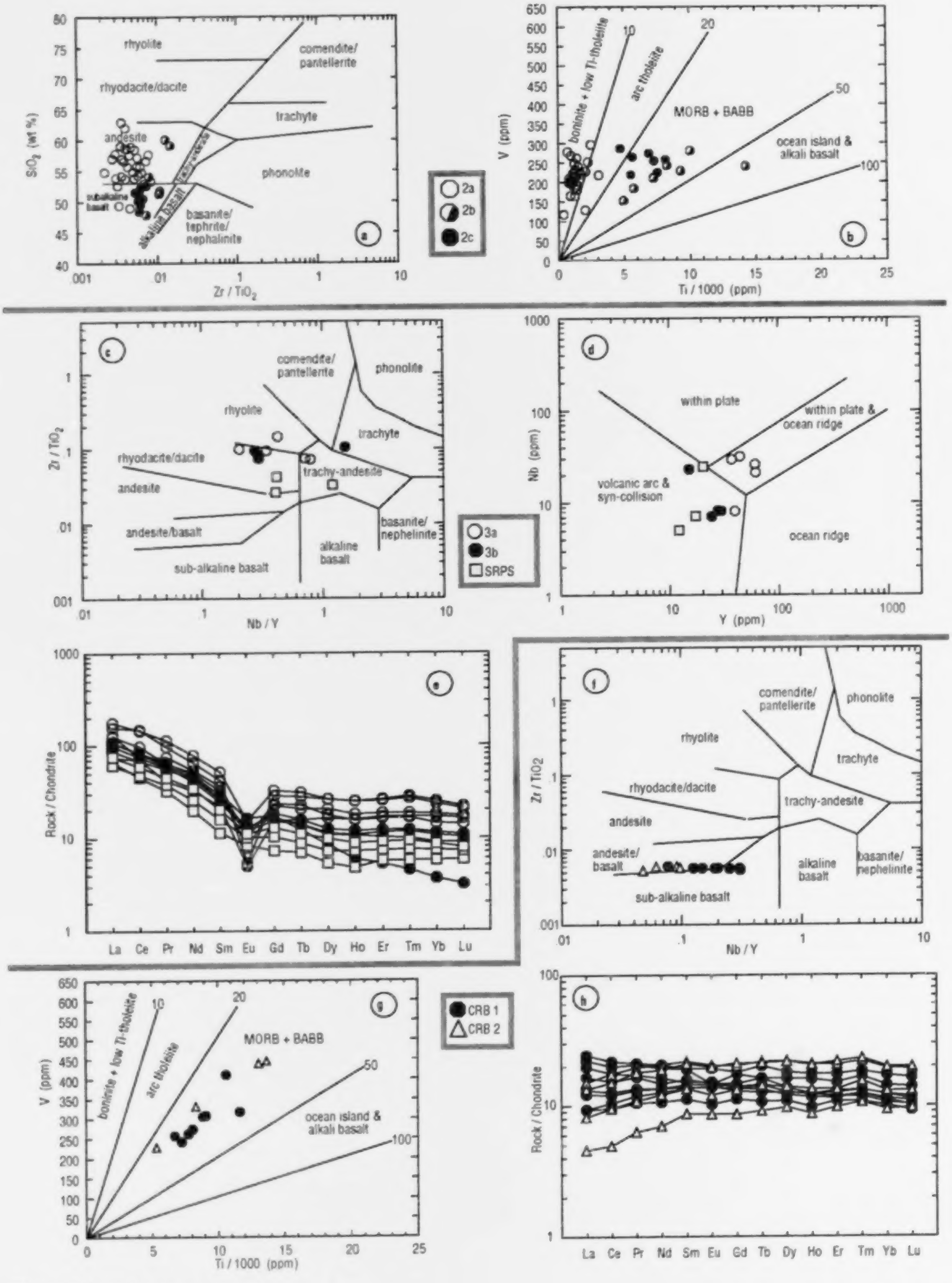


Figure 6. *(caption on next page)*

SUMMARY OF MINERALIZATION

Geochemical and geophysical information

Exploration in the Finlayson Lake area is hampered by thick overburden and the fact that most mineralization does not outcrop. Geochemical and geophysical techniques are therefore important for exploration in this area. A summary of available data[7] is given herein on: (i) stream and soil geochemistry, (ii) drift prospecting and till geochemistry, and (iii) regional geophysics.

Stream and soil geochemistry

Figures 7a to 7c present stream sediment sampling and geochemical data for the Finlayson Lake area published by the Geological Survey of Canada (Hornbrook and Friske, 1988). The sampling was done at an approximate density of one specimen per 10 km^2. Each specimen was analysed for twenty elements including common indicator elements for VMS deposits such as Cu, Pb, Zn and Ag. Anomalous results were obtained from creeks draining some previously known VMS occurrences (Yukon MINFILE, 2001, 105G 032, 034 and 040) including the Fetish (now the Wolverine deposit; Fig. 7). Most specimens collected proximal to Wolverine Lake returned elevated levels of zinc and barium with some specimens containing elevated levels of copper, lead, silver, molybdenum, cadmium and/or uranium and rarely gold (Hornbrook and Friske, 1988). Anomalous results were also obtained from several drainages where there were no known mineral occurrences. Follow-up exploration has since located showings in many of the anomalous creeks with the most significant discovery to date being that of Kudz Ze Kayah.

Drift prospecting and till geochemistry[8]

A drift prospecting and till geochemistry study by Plouffe (1989) in the Finlayson Lake district revealed several geochemically anomalous areas including one of anomalous gold, silver, arsenic, copper, lead and zinc around Wolverine Lake (Fig. 8). Abundance patterns of lead, zinc and copper did not correspond, suggesting multiple metal sources or redistribution of metals by hydromorphic processes. Discovery of the Wolverine polymetallic VMS deposit and other mineralized showings on the east side of Wolverine Lake in 1995 confirmed the significance of these anomalies and strongly supports use of till geochemical exploration in drift covered areas of the YTT.

Glacial transport and dispersion of mineralization significantly affect the interpretation of till geochemistry. The geochemistry of till at any point is a "lithological summation of source units up-ice from the site" (DiLabio, 1989, p. 649). Ore deposits masked by surficial cover may be located by tracing anomalous results from geochemical analyses of till, or visually recognizable ore fragments, up-flow of paleo-ice to their bedrock source (cf. Jackson, 1994). Ice-flow patterns for the Finlayson Lake area, based on glacial meltwater channels, were mapped by Jackson (1994) and are part of a Yukon wide compilation by Duk-Rodkin (1999). In general, in the eastern part of the Finlayson Lake area, the ice-flow patterns were generally to the east and south (Fig. 8a). In the west-central part of the Finlayson Lake area, the ice-flow pattern was generally to the west (Fig. 8a). More detailed patterns are shown on maps contained in Jackson (1994). The detailed maps reveal local perturbations. For example, at the south end of Wolverine Lake ice flow is to the southeast, consistent with the general ice direction, however, on the east side of the lake ice flow is to the northwest, opposite to the general direction. In the area of the Kudz Ze Kayah deposit, the general ice flow direction is west; however, in the valley that hosts the deposit, ice flowed to the northwest, transverse to the general direction. Therefore, an examination of local, as well as regional glacial movement should accompany any interpretation of drift prospecting results. It is also important to sample the same medium at each site in order to make meaningful comparisons between areas (see Plouffe, 1989, and Jackson, 1994 for descriptions of surficial material).

---

[7] Numerous property-scale geochemical and geophysical surveys have been carried out. Those that have been filed for assessment credit will become available for general viewing once the five-year confidentiality period has expired.

[8] The most recent compilation of till geochemistry for the Finlayson Lake map area is now available on CD-Rom (Bond et al. 2002); however, information from that study is not included within this report.

Figure 6. (preceding page) *Discrimination diagrams and chondrite-normalized REE plots for the Fire Lake metavolcanic unit (unit DMF/Unit 2), the Kudz Ze Kayah felsic metavolcanic unit (unit MK/Unit 3) and Campbell Range belt (CRB) rocks in the Finlayson Lake area (modified from Piercey et al. 1999).* ***a)*** *and* ***b)*** *Discrimination diagrams showing variations in suites 2a, 2b and 2c.* ***c)*** *and* ***d)*** *discrimination diagrams for suites 3a, 3b and the Simpson Range Plutonic Suite (SRPS).* ***e)*** *Chondrite-normalized REE plot for suite 3a and 3b felsic metavolcanic rocks and SRPS felsic intrusive rocks.* ***f)*** *and* ***g)*** *discrimination diagrams for CRB mafic metavolcanic rocks.* ***h)*** *Chondrite-normalized REE plot for CRB mafic metavolcanic rocks. a), c) and f) fields are from Winchester and Floyd (1977); b) and g) fields are modified from Shervais (1982); d) fields are from Pearce et al. (1984); e) and h) chondrite normalization values are from Taylor and McLennan (1985).*

Regional geophysics

Published geophysical data for the Finlayson Lake area consists of airborne Bouguer gravity surveys and airborne gamma ray spectometric, magnetic and very low frequency (VLF) electromagnetic data. Regional-scale magnetic surveys were flown with fixed-wing aircraft at a nominal elevation of 300 m above ground level on east-west lines spaced approximately 1.6 km apart. Results are presented as one inch to four mile (1:253 440) scale maps (Department of Mines and Technical Surveys, 1961a,b), and in more detail on a series of one inch to one mile (1:63 360) scale maps (Department of Mines and Technical Surveys, 1961c). The 1:253 440-scale maps have since been re-contoured and coloured versions are available for viewing in the DIAND library, Whitehorse. The regional geophysical information is also included on the digital Yukon geology compilation by Gordey and Makepeace (1999).

Large areas of intense positive magnetic response are underlain by mafic and ultramafic rocks of the CRB and the YTT. The anomalies are generally narrow and elongate over mafic rocks and broader over ultramafic rocks. A series of less intense positive magnetic anomalies were also recorded over the YTT rocks. Some of these anomalies occur proximal to the Fyre Lake and Wolverine deposits and may be associated with magnetite that occurs in the Kona zone at Fyre Lake and in banded iron formation horizons in the hanging wall at Wolverine.

Airborne gamma-ray spectometric, magnetic and VLF data were recently released and are available as 1: 150 000-scale coloured maps and profiles for part of the Finlayson Lake district including those areas hosting the Kudz Ze Kayah, GP4F, Wolverine and Fyre Lake deposits (NTS map sheets 105G/7 and parts of 2 & 8; Geological Survey of Canada, 1998; Gordey and Makepeace, 1999).

MINERAL DEPOSITS

A total of 51 mineral occurrences were reported within the Finlayson Lake area prior to the discovery of the Kudz Ze Kayah and Wolverine massive sulphide deposits in 1994/5. Exploration activity following the discoveries led to the reporting of numerous additional mineral occurrences and this number has now increased significantly (Fig. 5; Yukon MINFILE, 2001). Continued exploration has led to the discovery of the Ice and GP4F deposits, and significant new mineralization at Fyre Lake. The VMS deposits are described in the following section from oldest to youngest, followed by descriptions of significant VMS occurrences. Additional information can be found in Yukon MINFILE (2001)[9].

Fyre Lake

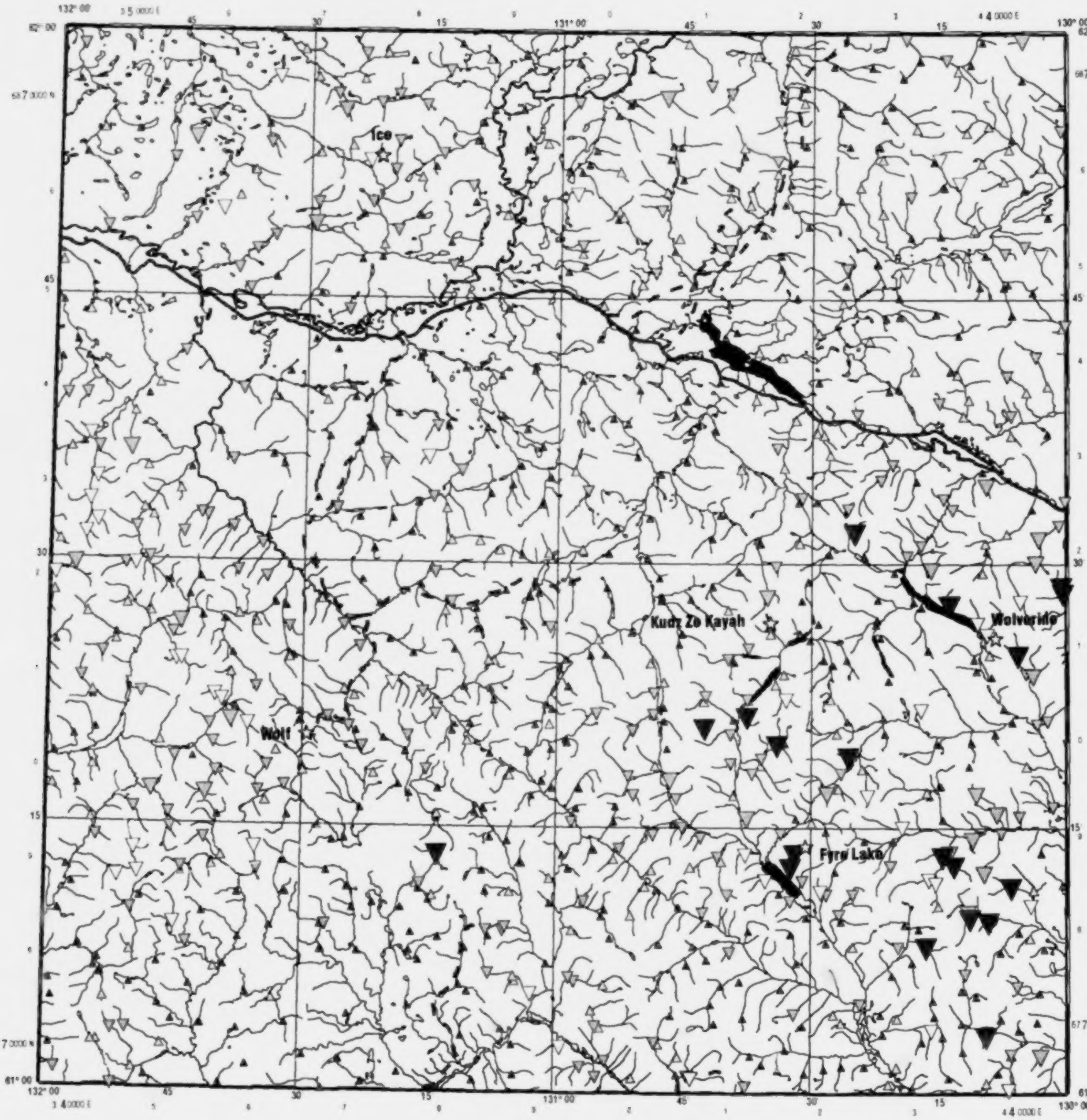
The Fyre Lake property (Yukon MINFILE, 2001, 105G 034; 61°13'35"N, 130°30'49"W) is located on the east side of Fire (formerly Fyre) Lake in the west-central part of the Finlayson Lake district (Figs. 1, 4, 5 and 9). Copper-cobalt-gold ± zinc-silver mineralization (Blanchflower et al., 1997; Deighton and Foreman, 1997; Foreman, 1998) is hosted by chlorite schist of the Fire Lake mafic metavolcanic unit (unit DMF/Unit 2) close to the contact with overlying carbonaceous phyllite of the Kudz Ze Kayah felsic metavolcanic unit (unit MKcp/Unit 3: Hunt and Murphy, 1998; Murphy and Piercey, 1999b). The main area of mineralization, known as the Kona deposit (Fig. 9), contains a resource of 8.2 million tonnes of 2.1% copper and 0.73 g/t gold (George Cross Newsletter (GCNL), 1998). The property geology and mineralization are summarized below and in Figure 9. More detail will be in Sebert et al. (in prep).

Property geology

The Fyre Lake area was mapped at 1:50 000 scale during this study (Fig. 9; Hunt and Murphy, 1998) and in more detail by staff of Columbia Gold Mines Ltd. (now Pacific Ridge Exploration; Blanchflower and Deighton, 1996; Blanchflower, 1997; Blanchflower et al., 1997; Deighton and Foreman, 1997; Foreman, 1998). The property is underlain primarily by the Fire Lake mafic metavolcanic unit (unit DMF/Unit 2: Figs. 3, 4). The majority of this unit, which hosts the Kona deposit, is

---

[9] Reports on most of the deposits and occurrences have been filed for assessment credit and will be available for public viewing after expiry of the five-year confidentiality period.


132° 00'
62° 00'
45
30
15
131° 00'
130° 00'
61° 00'
Ice
Kudz Ze Kayah
Wolverine
Wolf
Fyre Lake
687 0000 N
677 0000 N
3 4 0000 E
4 4 0000 E
☆ VMS Deposit
Copper (Cu) ppm
Percentile
4510.0 ▼ MAX
89.0 ▽ 98th
68.0 ▽ 95th
53.0 ▽ 90th
36.0 △ 70th
28.0 ▲ 50th
<2.0 · Below Detection
967 Samples
0 5 10 15
km

Topographic base produced by
SURVEYS AND MAPPING BRANCH,
DEPARTMENT OF ENERGY, MINES
AND RESOURCES

Copyright Her Majesty the Queen
in Right of Canada

TEN THOUSAND METRE
Universal Transverse Mercator Grid
ZONE 9, NAD 27

***Figure 7a.** Regional silt sample survey results for the Finlayson Lake map area (105G): copper (data from Hornbrook and Friske, 1988).*

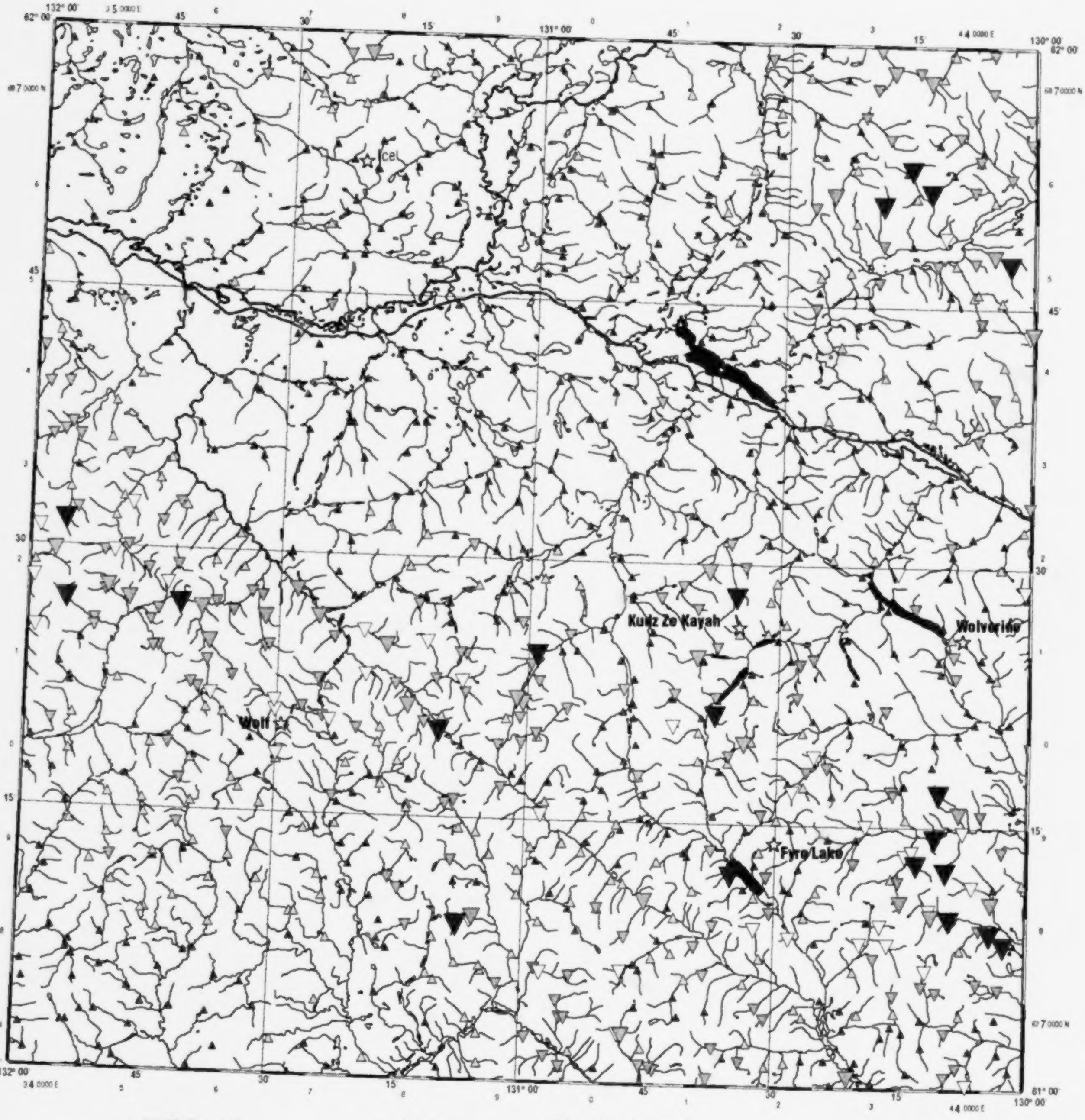

132° 00'
62° 00'
131° 00'
130° 00'
62° 00'
61° 00'
132° 00'
131° 00'
61° 00'
130° 00'
45'
30'
15'
Cel
Kudz Ze Kayah
Wolverine
Wolf
Fyre Lake
☆ VMS Deposit
Lead (Pb) ppm
▼ MAX Percentile
▼ 98th
▽ 95th
▼ 90th
△ 70th
▲ 50th
• Below Detection
967 Samples
Topographic base produced by
SURVEYS AND MAPPING BRANCH,
DEPARTMENT OF ENERGY, MINES
AND RESOURCES
Copyright Her Majesty the Queen
in Right of Canada
TEN THOUSAND METRE
Universal Transverse Mercator Grid
ZONE 9, NAD 27
0 5 10 15
km

Figure 7b. Regional silt sample survey results for the Finlayson Lake map area (105G): lead (data from Hornbrook and Friske, 1988).

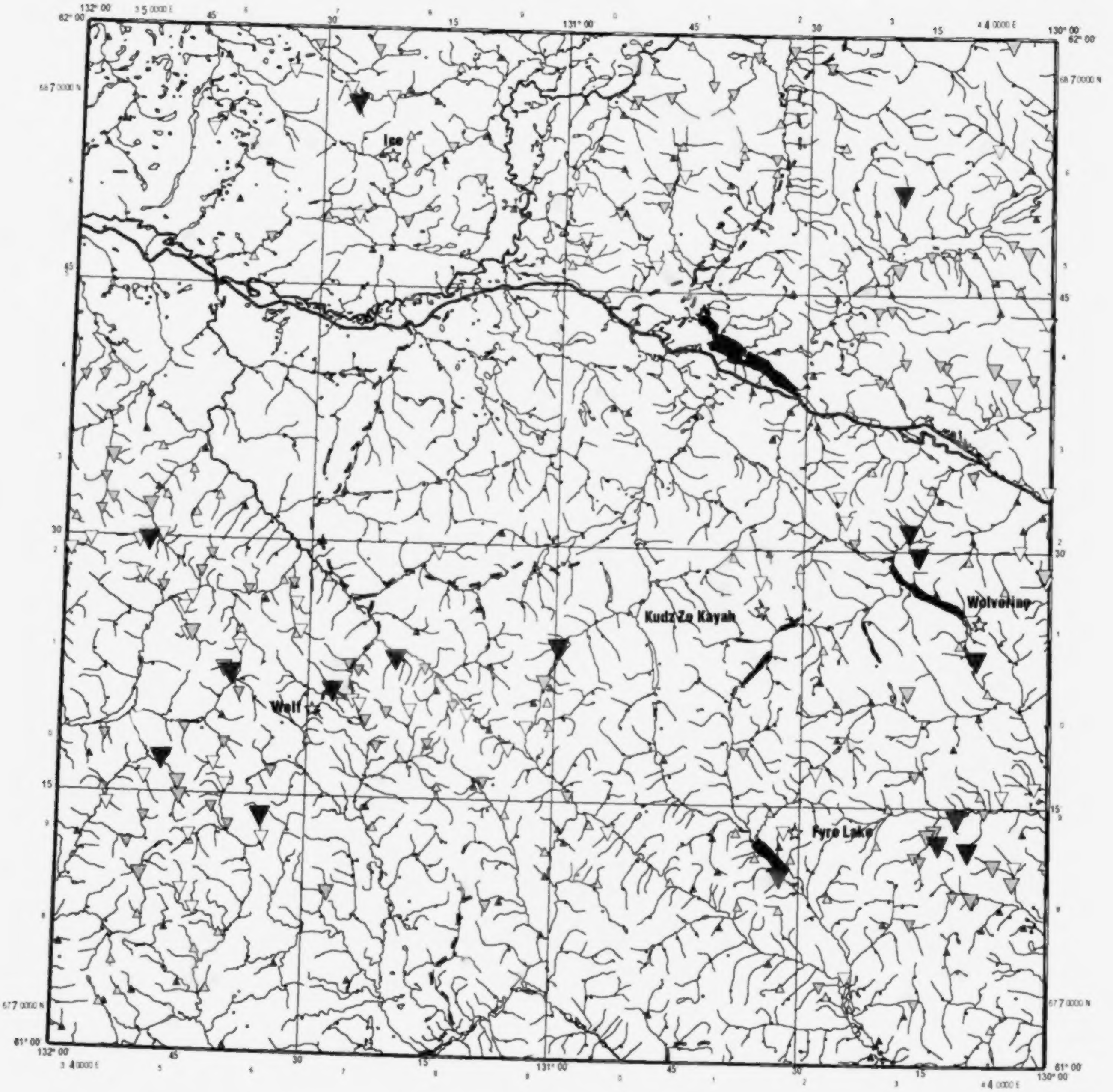
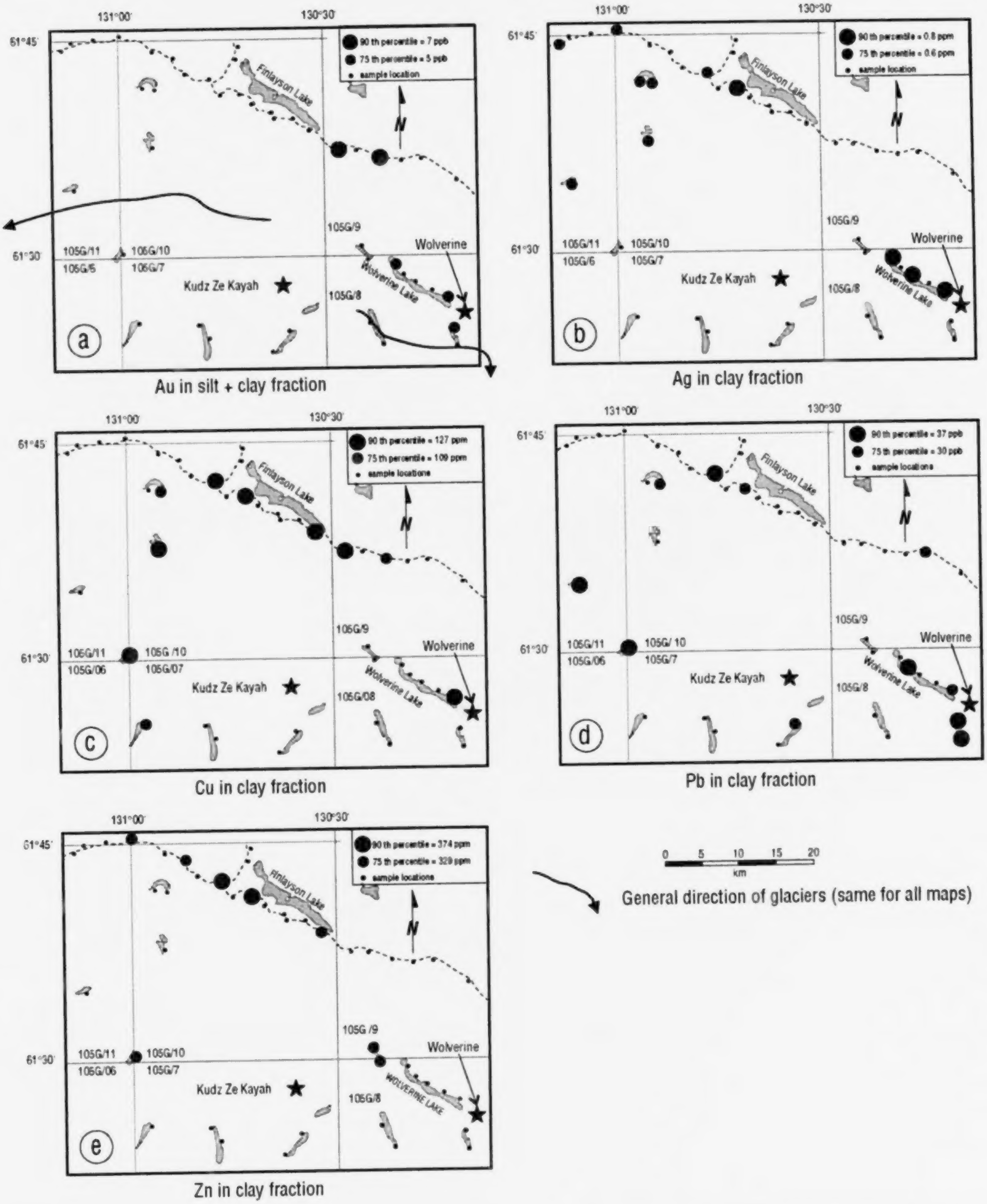

132° 00'
62° 00'
131° 00'
130° 00'
62° 00'
61° 00'
132° 00'
131° 00'
61° 00'
130° 00'
45'
30'
15'
Ice
Kudz Ze Kayah
Wolverine
Wolf
Fyre Lake
☆ VMS Deposit
Silver (Ag) ppm
Percentile
4.3 ▼ MAX
0.9 ▽ 98th
0.7 ▽ 95th
0.4 ▽ 90th
0.3 △ 70th
0.2 ▲ 50th
<0.2 • Below Detection
967 Samples
Topographic base produced by SURVEYS AND MAPPING BRANCH, DEPARTMENT OF ENERGY, MINES AND RESOURCES
Copyright Her Majesty the Queen in Right of Canada
TEN THOUSAND METRE Universal Transverse Mercator Grid ZONE 9, NAD 27
0 5 10 15
km

***Figure 7c.** Regional silt sample survey results for the Finlayson Lake map area (105G): silver (data from Hornbrook and Friske, 1988).*


131°00'
130°30'
61°45'
61°30'
90 th percentile = 7 ppb
75 th percentile = 5 ppb
sample location
Finlayson Lake
N
105G/11
105G/10
105G/5
105G/7
105G/9
105G/8
Wolverine
Wolverine Lake
Kudz Ze Kayah
a
90 th percentile = 0.8 ppm
75 th percentile = 0.6 ppm
b
90 th percentile = 127 ppm
75 th percentile = 109 ppm
sample locations
105G/06
105G/07
105G/08
c
90 th percentile = 37 ppb
75 th percentile = 30 ppb
d
90 th percentile = 374 ppm
75 th percentile = 320 ppm
WOLVERINE LAKE
e
0 5 10 15 20
km
General direction of glaciers (same for all maps)

Au in silt + clay fraction

Ag in clay fraction

Cu in clay fraction

Pb in clay fraction

Zn in clay fraction

Figure 8. *Results of till geochemical analysis in the Wolverine Lake area. Data from Plouffe (1989). Diagrams modified from Plouffe (1989) and Plouffe and Jackson (1992, 1995). Glacial direction information, shown in a, is from Duk-Rodkin (1999).*

made up of a dark green, fine-grained chlorite-quartz and chlorite-actinolite-quartz schist and phyllite package. The chloritic schist and phyllite package is underlain by at least 50 m of carbonaceous phyllite, and overlain by a sequence, at least 700 m thick, of fine-grained, finely laminated, well foliated, grey to black carbonaceous phyllite, lesser metasiltstone and metasandstone, and minor limestone (unit MKcp/Unit 3). The under- and overlying carbonaceous phyllites are indistinguishable from one another except by stratigraphic position. Locally, felsic metavolcanic rocks overlie the upper carbonaceous phyllite (unit MK/Unit 3). The dominant foliation is parallel to compositional layering and dips shallowly eastward; lineations plunge shallowly to the southeast, parallel to the trend of mineralization at about 130° (Deighton and Foreman, 1997).

Schistose host rocks to the mineralization are interpreted as a succession of mafic to intermediate flows and tuffs (Fig. 10a) with intercalated volcaniclastic and volcanically derived fine-grained sedimentary rocks (Deighton and Foreman, 1997; Foreman, 1998). The strata are part of a regionally persistent chlorite schist and phyllite unit (unit DMF/Unit 2: Figs. 3, 4), spatially associated with voluminous mafic and ultramafic intrusive rocks (Murphy, 1998; Murphy and Piercey, 1999b). Murphy (1998) interprets the ultramafic rocks as sills, fed by dykes which intruded along a syn-sedimentary fault (not preserved). This fault is inferred to have formed the northeast side of the basin in which the Kona massive sulphide deposit formed.

The underlying carbonaceous phyllite (unit cp on Fig. 9; Fig. 10b) outcrops in Kona creek and was intersected in drilling in the Kona zone in drill hole 97-97 which terminated in metasedimentary rocks beneath mafic schists (Foreman, 1998). It is not clear if the carbonaceous phyllite is structurally juxtaposed or if it represents a separate unit. Its presence as a separate stratigraphic unit would suggest that local faulting likely controlled sedimentation. Such a fault may also have acted as a conduit for mineralizing hydrothermal solutions (Hunt and Murphy, 1998; Murphy, 1998).

Early descriptions of the Fyre Lake property (cf. Stroshein, 1991) show the overlying metasedimentary rocks in thrust fault contact with the underlying mafic metavolcanic rocks, however, recent mapping found no evidence for a thrust fault contact. The contact between the two successions appears to be transitional and is marked by an interval of intercalated quartz-biotite ± chlorite and chlorite ± biotite ± quartz schist 6 to 200 m thick, which thickens to the west (included within unit DMF on Fig. 9; in mixed metasedimentary and metavolcanic rocks on Fig. 12; and as unit INVS in Columbia Gold Mines Ltd. company reports; Foreman, 1998). This interval is described by Foreman (1998) as a zone of interfingering terrigenous sediments and volcanically derived sediments and/or flows.

The affiliation of felsic rocks that overlie the upper carbonaceous phyllite is not clear (Fig. 9, unit MK). They are lithologically similar to felsic metavolcanic rocks in the Kudz Ze Kayah felsic metavolcanic unit (unit Mk/Unit 3). However, they also show similarities to metamorphosed felsic rocks of the Simpson Range Plutonic Suite which is exposed to the east and south of the deposit (units MSgs, MSg on Fig. 9).

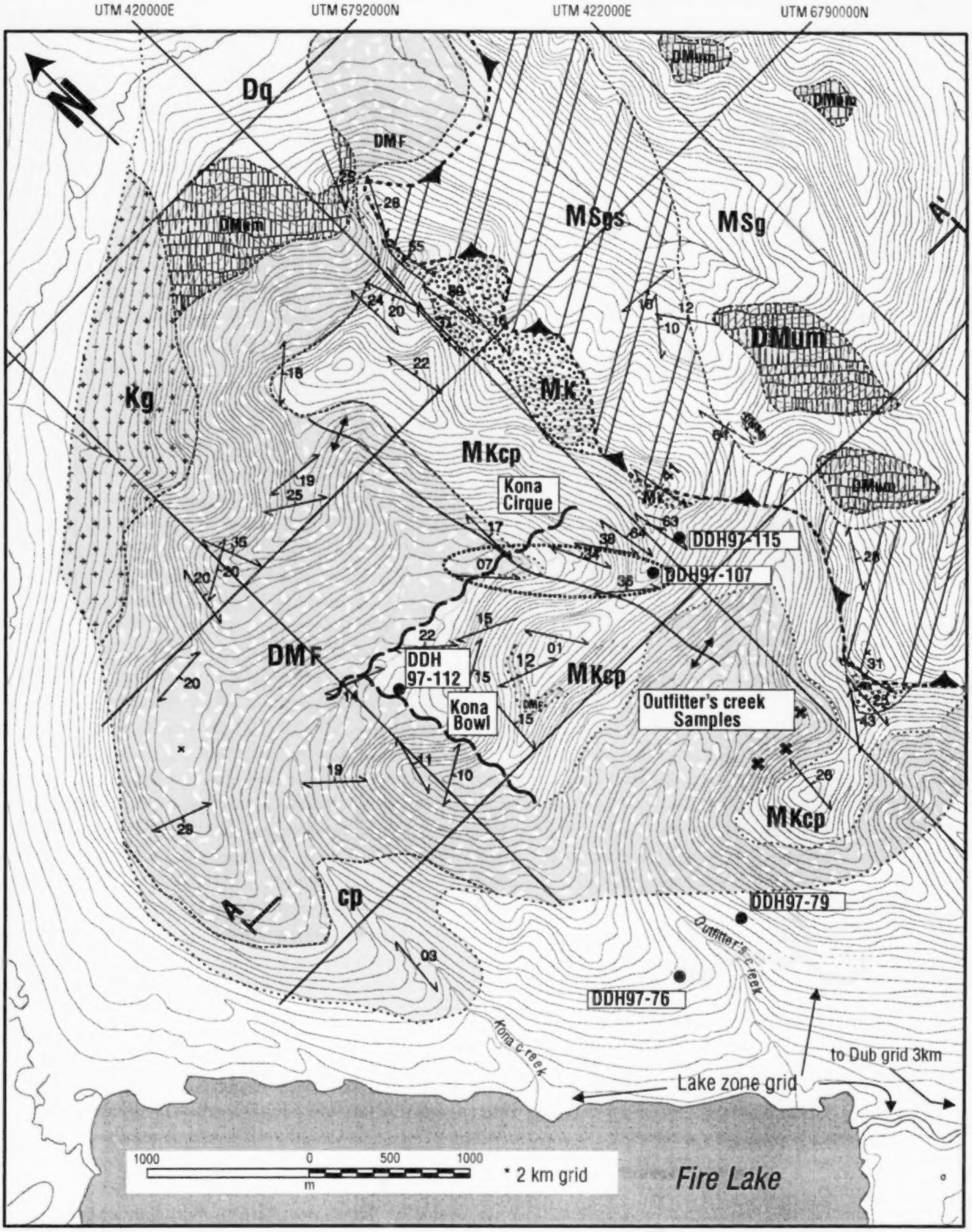
Petrography

Specimens of the chlorite schist and phyllite sequence, and felsic rocks overlying the carbonaceous phyllite were examined in thin section by Leitch (1998). Summary results follow. Detailed descriptions are in Appendix VI-3.

Specimens of the chloritic schist and phyllite sequence (Appendix VI-3: specimens JH96-62, JH97-57, 59, 60, 70) are composed of amphibole (0-60%), quartz (10-40%), relict plagioclase (10-30%), chlorite (0-20%), biotite (1-10%), epidote (0-10%), carbonate (0-3%), garnet (0-2%), minor sericite and accessory rutile, apatite, sphene and opaques. Locally, the schists are made up of alternating quartz-plagioclase-rich laminations and amphibole-rich or chlorite-biotite-epidote-garnet-rich laminations. Locally, pale, quartzose boudins 2-20 cm across occur within the schists. Rare orange-red garnet occurs as porphyroblasts up to 4 mm in diameter (Deighton and Foreman, 1997). The specimens examined are classified by Leitch (1998) as mainly metagabbro/diabase and lesser probably intermediate to mafic volcanic rock.

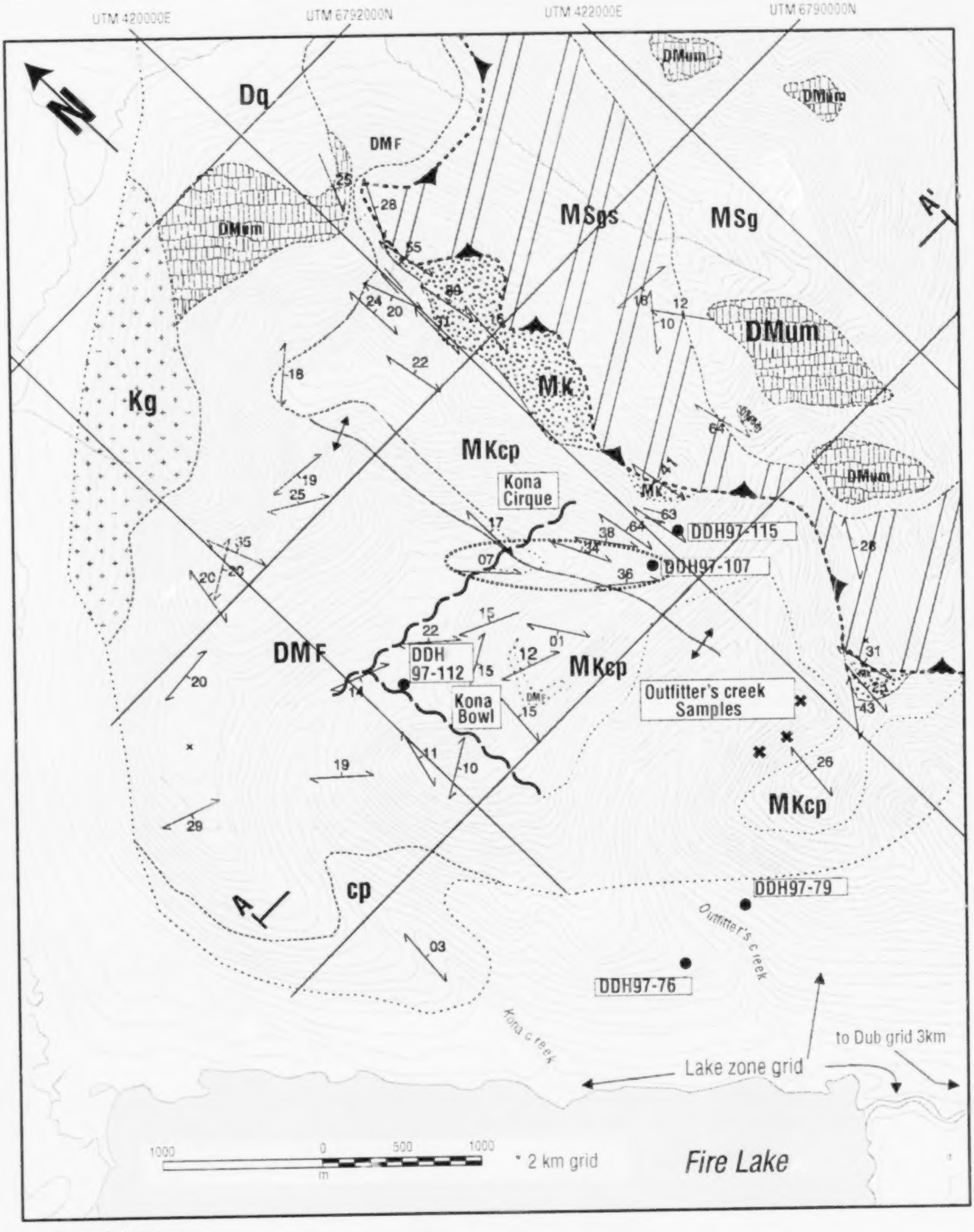
Locally, the chlorite schist and phyllite sequence contains pale layers (Appendix VI-3: specimens JH97-67 and 77) composed primarily of quartz and feldspar that are likely metamorphosed felsic or intermediate volcanic rocks with chlorite-sericite-epidote ± biotite alteration. Locally, the schists are composed primarily of amphibole (likely tremolite-actinolite) and magnesian chlorite (Appendix VI-3: specimen JH97-65) and are interpreted to be metamorphosed ultramafic rocks.

Two specimens (Appendix VI-3: JH96-KZFV, JH97-75) of the felsic rocks were examined by Leitch (1998). Specimen JH97-KZFV is composed of 60-65% (likely albitic) plagioclase, 20% quartz, 10% sericite, 5% chlorite and biotite, and 1-2% opaques (limonite and possibly rutile). Rounded, relict plagioclase phenocrysts, up to 1 mm


UTM 420000E
UTM 6792000N
UTM 422000E
UTM 6790000N
N
Dq
DMF
DMum
Kg
MSgs
MSg
A'
MK
MKcp
Kona Cirque
DDH97-115
DDH97-107
DDH 97-112
Kona Bowl
Outfitter's creek Samples
DMF
cp
A
DDH97-79
DDH97-76
Outfitter's creek
Kona creek
to Dub grid 3km
Lake zone grid
Fire Lake
1000 0 500 1000
m
* 2 km grid

* UTM zone 9, NAD 27

Figure 9a. Fyre Lake bedrock geology map (modified from Hunt and Murphy, 1998; Sebert and Hunt, 1999). Also shown are the locations of Kona Cirque, Kona Bowl, the Lake zone and Outfitter's Creek. Oval dashed line shows the area of the Kona deposit and is enlarged in Figure 9b.


UTM 420000E
UTM 6792000N
UTM 422000E
UTM 6790000N
N
Dq
DMF
DMum
MSgs
MSg
A'
MK
MKcp
Kg
Kona Cirque
DDH97-115
DDH97-107
DDH 97-112
Kona Bowl
Outfitter's creek Samples
cp
A
DDH97-79
DDH97-76
Outfitter's creek
Kona creek
to Dub grid 3km
Lake zone grid
1000
0
500
1000
m
* 2 km grid
Fire Lake

* UTM zone 9, NAD 27

Figure 9a. *Fyre Lake bedrock geology map (modified from Hunt and Murphy, 1998; Sebert and Hunt, 1999). Also shown are the locations of Kona Cirque, Kona Bowl, the Lake zone and Outfitter's Creek. Oval dashed line shows the area of the Kona deposit and is enlarged in Figure 9b.*

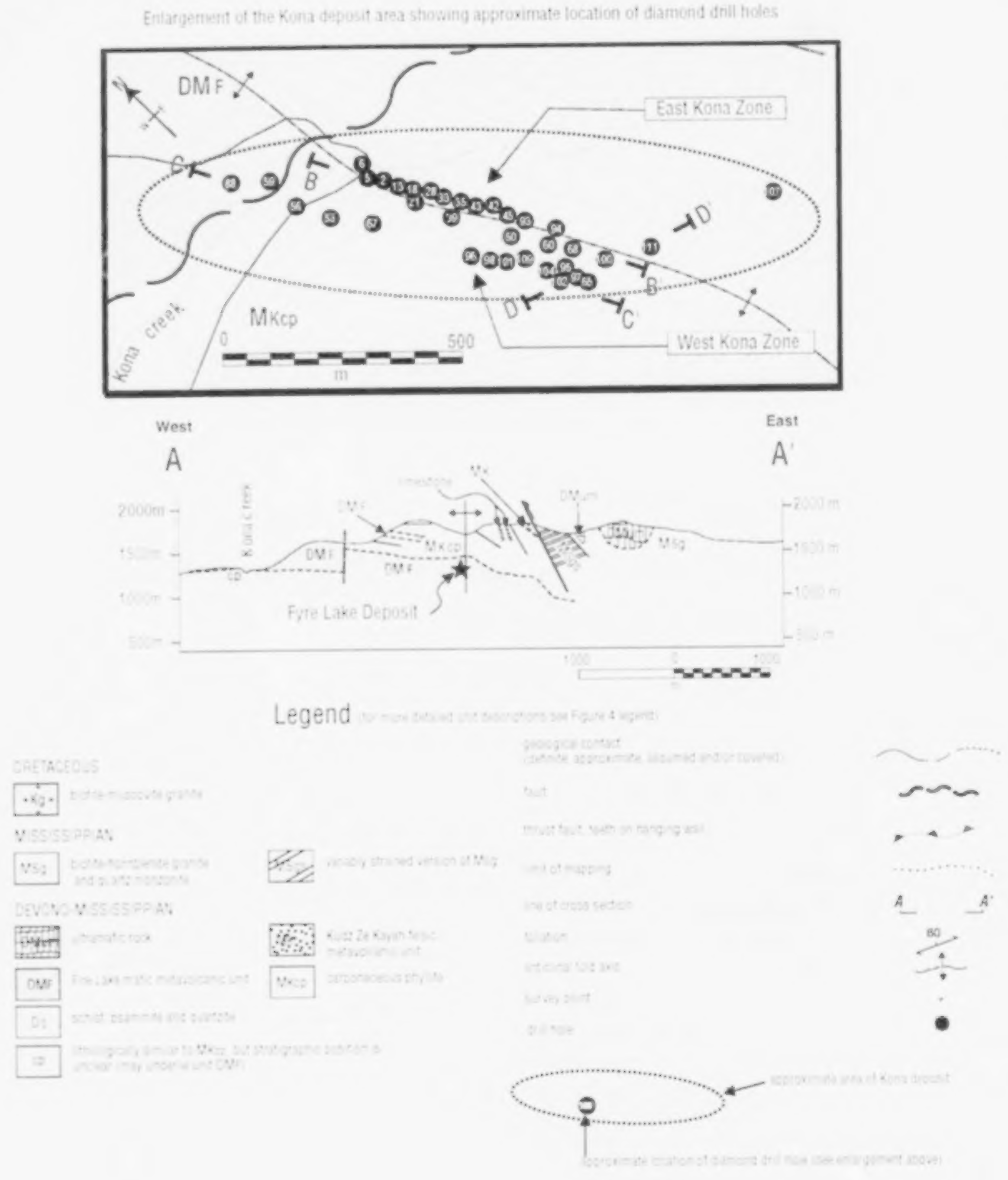

Enlargement of the Kona deposit area showing approximate location of diamond drill holes
N
DM F
East Kona Zone
West Kona Zone
C
B
D'
B'
D
C'
MKcp
Kona creek
0
500
m
West
East
A
A'
2000m
1500m
1000m
500m
2000 m
1500 m
1000 m
500 m
Kona creek
limestone
Mx
DM F
DMum
MKcp
MSg
cp
Fyre Lake Deposit
1000
0
1000
m
Legend (for more detailed unit descriptions see Figure 4 legend)
CRETACEOUS
Kg
biotite-muscovite granite
MISSISSIPPIAN
MSg
biotite-hornblende granite and quartz monzonite
variably strained version of MSg
DEVONO-MISSISSIPPIAN
DMum
ultramafic rock
Kudz Ze Kayah felsic metavolcanic unit
DMF
Fyre Lake mafic metavolcanic unit
MKcp
carbonaceous phyllite
Ds
schist, psammite and quartzite
cp
lithologically similar to MKcp, but stratigraphic position is unclear (may underlie unit DMF)
geological contact (definite, approximate, assumed and/or covered)
fault
thrust fault, teeth on hanging wall
limit of mapping
line of cross section
A
A'
foliation
60
anticlinal fold axis
survey point
drill hole
approximate area of Kona deposit
approximate location of diamond drill hole (see enlargement above)

Figure 9b. *Top: enlargement of the Kona deposit area showing the approximate location of diamond drill holes and the cross section and long section locations in Figure 12. Middle: cross section A-A' (the location of which is shown in Figure 9a). Bottom: legend for Figure 9.*

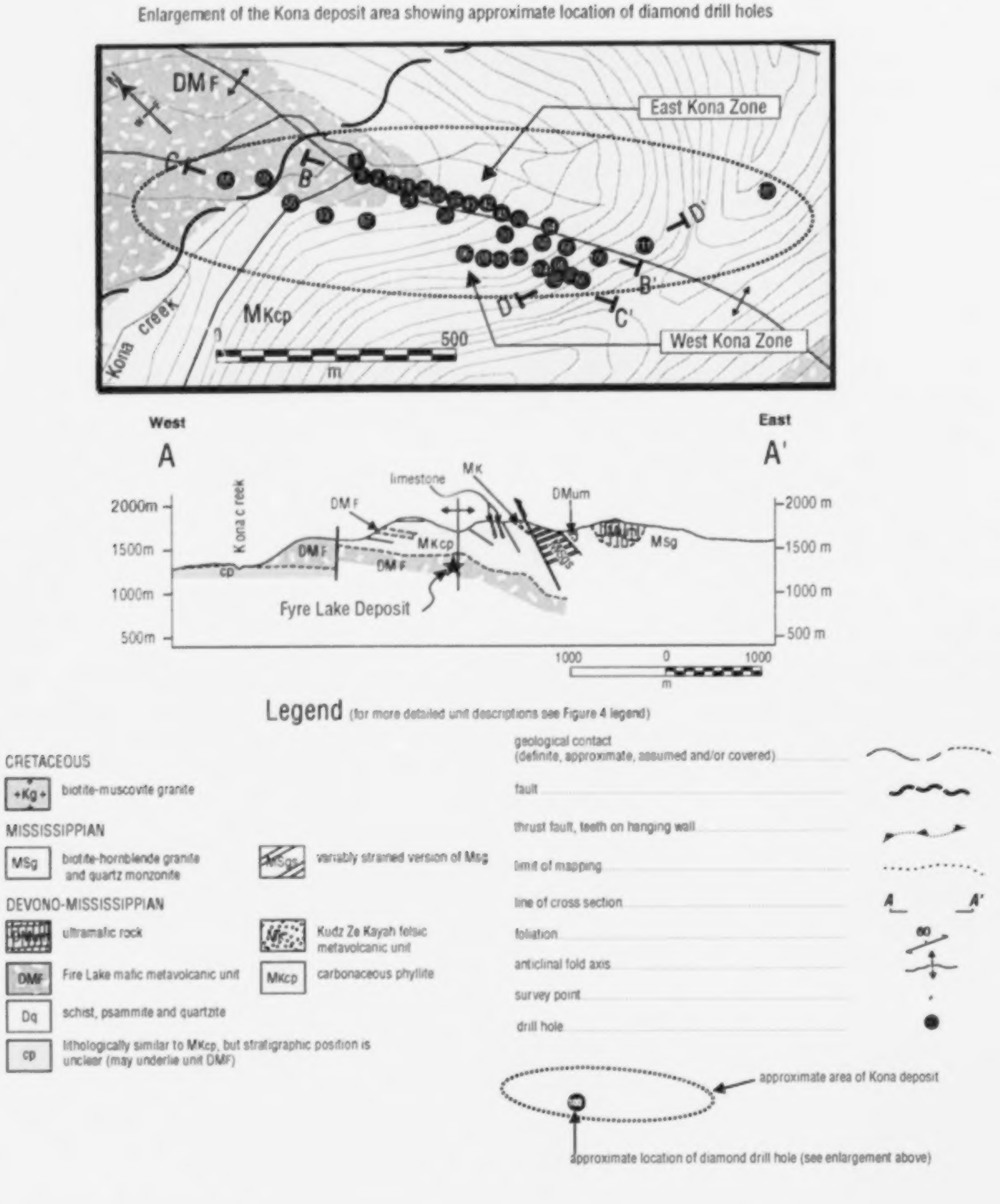

Enlargement of the Kona deposit area showing approximate location of diamond drill holes
DMF
East Kona Zone
B
C
D'
B'
D
C'
MKcp
Kona creek
0
500
m
West Kona Zone
West
East
A
A'
Kona creek
limestone
MK
DMF
DMum
MKcp
MSg
MSgs
cp
Fyre Lake Deposit
2000m
1500m
1000m
500m
2000 m
1500 m
1000 m
500 m
1000
0
1000
m
Legend (for more detailed unit descriptions see Figure 4 legend)
CRETACEOUS
+Kg+ biotite-muscovite granite
MISSISSIPPIAN
MSg biotite-hornblende granite and quartz monzonite
MSgs variably strained version of MSg
DEVONO-MISSISSIPPIAN
DMum ultramafic rock
MF Kudz Ze Kayah felsic metavolcanic unit
DMF Fire Lake mafic metavolcanic unit
MKcp carbonaceous phyllite
Dq schist, psammite and quartzite
cp lithologically similar to MKcp, but stratigraphic position is unclear (may underlie unit DMF)
geological contact (definite, approximate, assumed and/or covered)
fault
thrust fault, teeth on hanging wall
limit of mapping
line of cross section
A
A'
foliation
60
anticlinal fold axis
survey point
drill hole
approximate area of Kona deposit
approximate location of diamond drill hole (see enlargement above)

Figure 9b. Top: enlargement of the Kona deposit area showing the approximate location of diamond drill holes and the cross section and long section locations in Figure 12. Middle: cross section A-A' (the location of which is shown in Figure 9a). Bottom: legend for Figure 9.

in diameter, occur in a fine-grained matrix of quartz and plagioclase with minor sericite and chlorite. The protolith appears to have been plagioclase-porphyritic felsic volcanic rock, possibly of dacitic composition. Specimen JH97-75 consists of about 1-mm-thick laminae of alternating quartz-rich, possible feldspar-rich, and sericite-carbonate-rich composition. Locally, larger relict crystals (possibly K-feldspar) are preserved suggesting a possible former porphyritic rock of felsic to intermediate composition.

Metamorphism

The presence of biotite and garnet indicate that pressure-temperature conditions reached upper greenschist grade in the Fyre Lake area. Garnet porphyroblasts rimmed by chlorite suggest retrograde greenschist metamorphism overprints an earlier higher-grade phase (Sebert, 1997).

Lithogeochemistry

Specimens of mineralization-hosting and non-mineralization-hosting chlorite schist were collected from the Fyre Lake area for lithogeochemical analysis. Results of X-ray fluorescence (XRF) and inductively coupled mass spectrometry (ICPMS) are in Appendix VI-2. The data are being analysed as part of an ongoing study of the Fyre Lake deposit (preliminary results are in Sebert and Hunt, 1998) and as part of a regional study of the Finlayson Lake district (preliminary results are in Piercey et al., 1999). Following is a summary of the results to date.

Analysis of chlorite schist from the Fire Lake area indicates there are distinct chemical differences between chlorite schists that host the Kona deposit (Kona cirque specimens) and those that are unmineralized (Lake zone, Outfitter's creek and Kona bowl specimens). In general, the specimens plot in the basalt to andesite fields on an SiO_2 versus Zr/TiO_2 rock classification diagram (Fig. 11a) and are similar to specimens of unit DMF/Unit 2 collected elsewhere in the Finlayson Lake district (see Figs. 6a,b). However, on a V versus Ti tectonic affinity diagram distinct differences are apparent (Fig. 11b). Specimens of chlorite schist that hosts the Kona deposit cluster in the boninite and low Ti-tholeiite field, but non-mineralization-hosting chlorite schist specimens plot in the mid-ocean-ridge basalt (MORB) and back-arc basin basalt (BABB) field. This difference is also seen in rare-earth element (REE) plots for the chlorite schists. The pattern for Kona deposit host chlorite schists is similar to that for boninitic rocks (Figs. 11c, d), but the pattern for non-deposit hosting chlorite schists is similar to that for arc-related tholeiitic rocks. Differences between the chlorite schists can also be seen on other plots, for example MgO versus Zr (Fig. 11e) and Cr versus TiO_2 (Fig. 11f).

Overall, the chemistry of metavolcanic rocks in the Fyre Lake area suggests at least some of them were deposited in an arc-related environment influenced by subduction processes; see Sebert and Hunt (1999) and Sebert et al. (in prep) for more details. However, the tectonic implications of the presence of boninitic rocks is not yet clear. Boninitic rocks usually occur associated with ophiolitic sequences in back-arc basin and forearc settings, for example the Troodos ophiolite in Cyprus and the Izu-Bonin arc in the south Pacific (cf. Crawford, 1989). However, no typical ophiolitic sequence appears to be present in the Fire Lake area, although thick ultramafic rocks are spatially associated with unit DMF/Unit 2 (Figs. 5, 9; Hunt and Murphy, 1998).

Deposit description

The main mineralization on the Fyre Lake property is known as the Kona deposit. It is located in Kona cirque at the head of Kona creek (Fig. 9). Mineralization within this deposit occurs as two zones of massive to semi-massive sulphide and magnetite mineralization, designated East and West Kona (Figs. 9b, 10c,d, e, 12); the East Kona mineralized zone is divided into upper and lower horizons (Figs. 12 a, b; Blanchflower, 1997; Deighton and Foreman, 1997; Foreman, 1998). The zones are separated by an inferred steeply dipping reverse fault that down-drops the west side about 100 m based on the relative elevation of the metasedimentary-metavolcanic contact (Foreman, 1998). Weakly quartz-chlorite-altered schist occurs in the footwall rocks, however, it is not clear if the chlorite is due to hydrothermal alteration or metamorphism (C. Sebert,

Figure 10. *(next page) Fyre Lake deposit photographs:* ***a)*** *mafic volcanic breccia preserved in a pendant near the Fyre Lake deposit; this breccia may represent a protolith for some of the mafic metavolcanic rocks,* ***b)*** *folded carbonaceous phyllite exposed in Kona Creek,* ***c)*** *and* ***d)*** *massive sulphide mineralization from the east Kona zone,* ***e)*** *siliceous sulphide mineralization from the west Kona zone,* ***f)*** *fractured pyrite with chalcopyrite, pyrrhotite and sphalerite; reflected light + plane polarized light; field of view = 1.7 mm (VanRanden, 1997; Leitch, 1998), and* ***g)*** *pitted magnetite porphyroblast with exsolution lamellae of hematite (light grey); reflected light + plane polarized light; field of view = 0.87 mm (VanRanden, 1997; Leitch, 1998).*

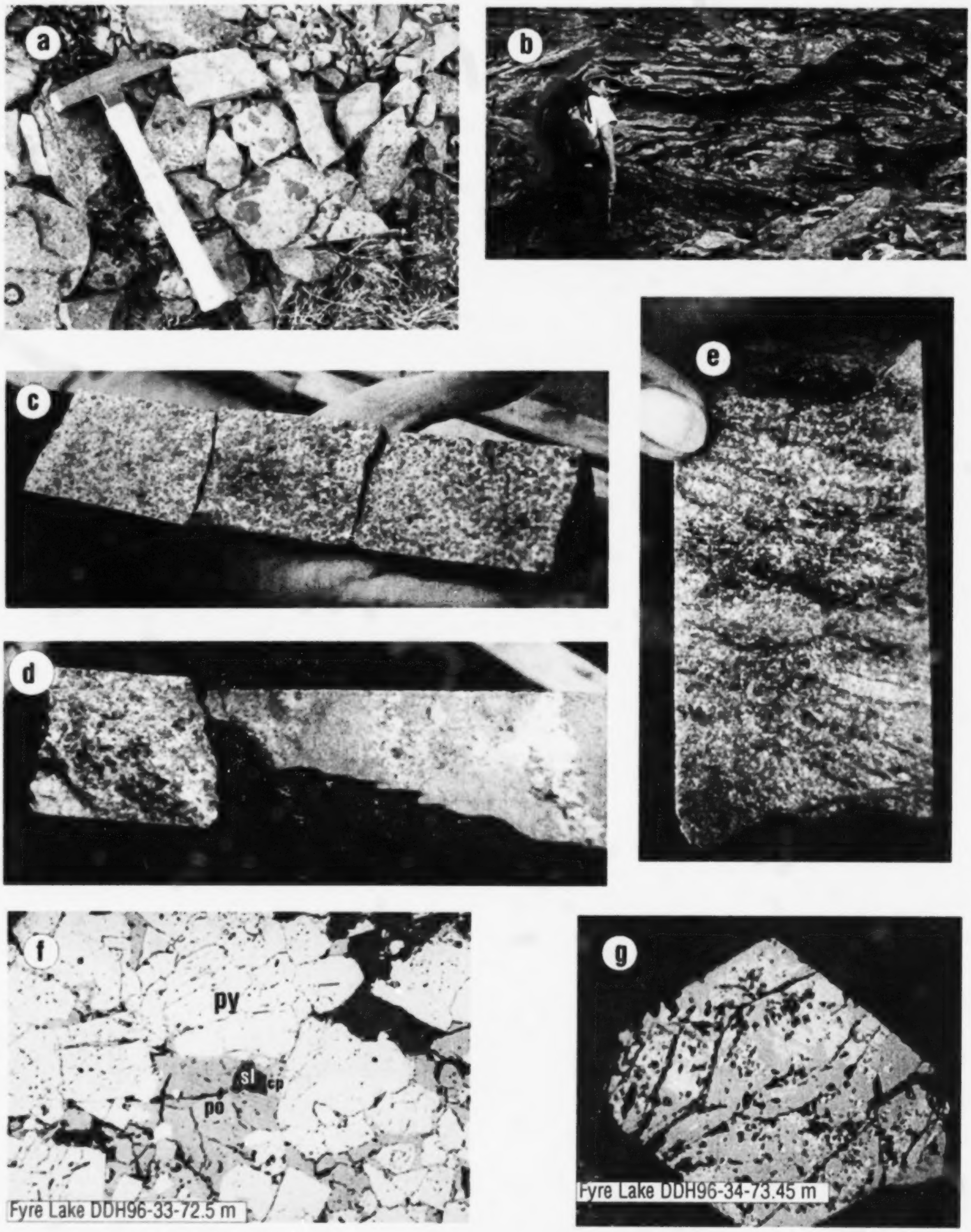

a
b
c
d
e
f
py
sl
cp
po
Fyre Lake DDH96-33-72.5 m
g
Fyre Lake DDH96-34-73.45 m

Figure 10. *(caption on previous page)*

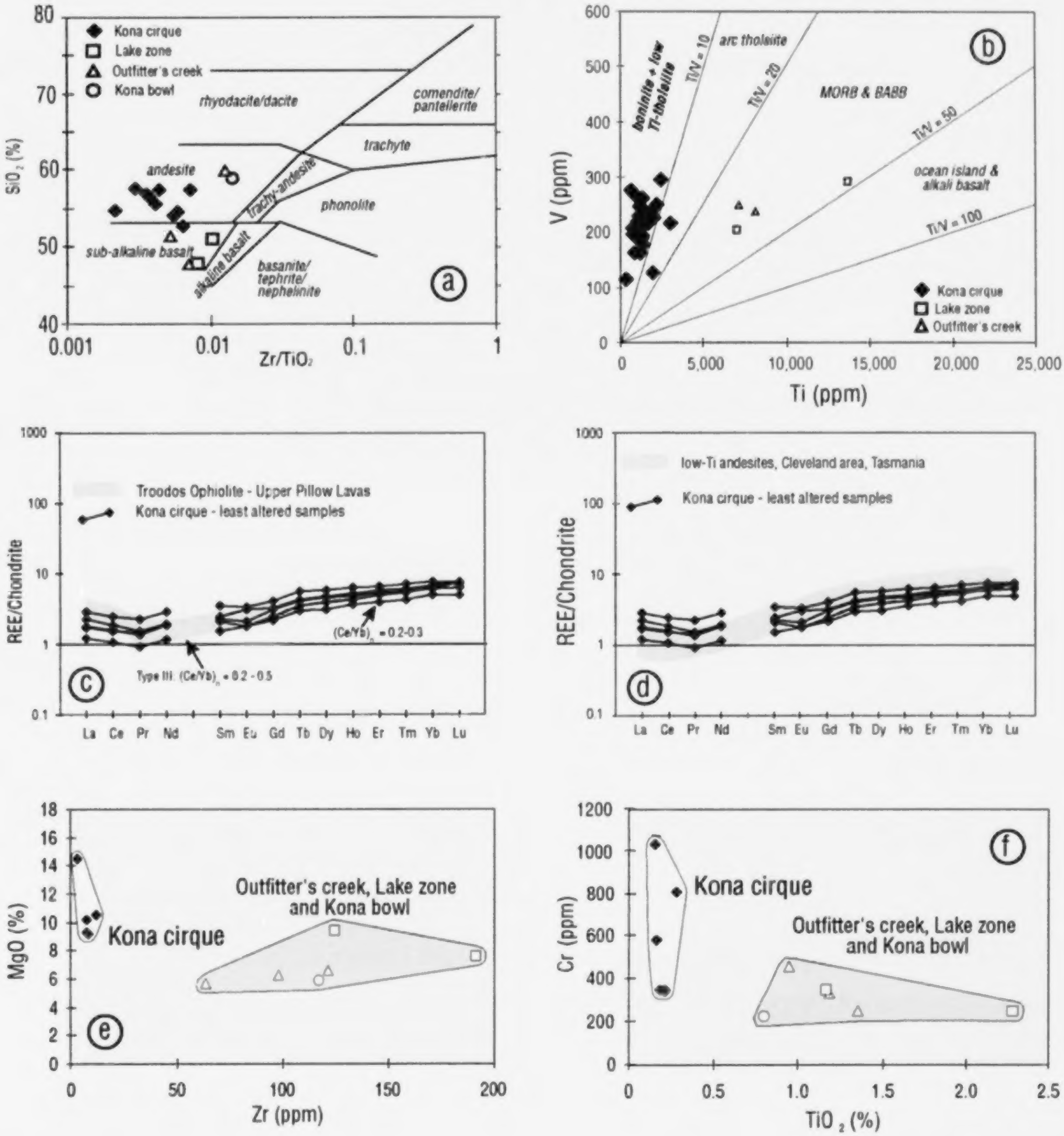


Figure 11. *Discrimination diagrams and chondrite-normalized REE plots for mafic metavolcanic rocks from the Fyre Lake property (modified from Sebert and Hunt, 1999, and Sebert et al., in prep). a), b), e) and f) Discrimination diagrams showing variations in mafic metavolcanic rocks from Kona cirque, the Lake zone, Outfitter's creek and Kona bowl; symbols in e) and f) are the same as those in a) and b). c) and d) Chondrite-normalized REE plots for Kona cirque mafic metavolcanic rocks compared respectively to boninitic rocks from the Troodos Ophiolite, Cyprus and the Cleveland area, Tasmania. a) fields are from Winchester and Floyd (1977); b) fields are modified from Shervais (1982); c) and d) chondrite values are from Evensen et al. (1978), Troodos Ophiolite data from Cameron (1985), Cleveland data from Brown and Jenner (1989).*

pers. comm., 1998).

An approximately 15 million tonne mineralized zone, 1500 m long by 250 m wide, encompasses all of the massive and semi-massive Kona deposit mineralization intersected to date (Foreman, 1998). Within this zone there is an open pit target made up of the near-surface portions of the East and West Kona zones (Figs. 12 b, c), and an underground target made up of the high-grade central portions of the East Kona zone and chalcopyrite-rich sections of West Kona zone that consistently have higher cobalt and gold values (Foreman, 1998).

• East Kona zone - lower horizon

The East Kona zone lower horizon occurs over a strike length of at least 870 m and is between 100 and 150 m wide (Foreman, 1998). It has been divided into north and south portions separated by an apparent gap in the horizon (Fig. 12b). The northern portion is 3-16 m thick and the southern portion is 2-11 m thick.

Composition of the northern portion varies from bottom to top (Foreman, 1998). The lower part is made up of 65 to 75% massive sulphide with 25 to 35% discontinuous, thin (average 1 m thick) massive magnetite layers. The sulphide mineralization is dominantly made up of layers of fine- to medium-grained pyrite with 3- to 6-m-thick local concentrations of chalcopyrite and pyrrhotite which occur as 2- to 10-cm-thick bands. The upper 0.5 to 1.5 m of the sulphide mineralization is predominantly made up of pyrite with 2 to 6% sphalerite, locally concentrated into 1- to 2-cm-thick bands. The core consists of massive, fine-grained, magnetite-rich layers with about 5% pyrite + chalcopyrite, in a carbonate and/or quartz groundmass. The upper part is predominantly massive, fine- to medium-grained pyrite with 3 to 5% chalcopyrite.

The southern portion of the East Kona zone lower horizon (Fig. 12b) also varies in composition from top to bottom. It is similar in appearance to the northern portion, except that locally the lower sulphide portion contains 0.5- to 3-m-thick layers of banded semi-massive (rather than massive) sulphide mineralization, and disseminated to semi-massive banded magnetite, rather than massive magnetite, overlies the sulphide mineralization (Foreman, 1998).

Petrography

Specimens of schist and massive sulphide mineralization from the East Kona zone lower horizon were examined by VanRanden (1997) and Leitch (1998). The results, given in detail in Appendix VI-3, are summarized below.

The immediate footwall to the lower horizon is made up of alternating foliae of chlorite and quartz plus minor carbonate, sphene and possibly hydrobiotite, and contains magnetite euhedra up to 3.5 mm across. Away from the lower horizon (Appendix VI-3: specimen DDH FL96-33-76.6 m), the footwall composition changes to fibrous amphibole in a matrix of possible plagioclase and quartz with lesser biotite and minor opaques including euhedral magnetite up to 0.25 mm across.

Lower horizon massive sulphide mineralization (Appendix VI-3: specimens DDH FL96-33-70.8 m, 71.48 m, 72.5 m, 72.9 m and 73.1 m, DDH FL96-34-71.8 m, 72.3 m and 73.45 m) is primarily composed of pyrite, chalcopyrite, sphalerite and lesser pyrrhotite (Fig. 10f), with minor disseminated magnetite occurring in magnetite-rich layers within a gangue of quartz-chlorite and lesser carbonate, sericite and rare amphibole. The lower horizon is locally cut by veinlets of carbonate-quartz-epidote. Green garnet porphyroblasts are also present locally and are partly replaced/pseudomorphed by carbonate-chlorite-sericite; some are sieve-textured due to inclusions of pyrite, and possibly magnetite and sphalerite. Magnetite porphyroblasts, present in only one specimen from the lower horizon, contain exsolution lamellae of hematite (Fig. 10g). In this specimen there are also rare, zoned pyrite crystals. Locally, the sulphides are strongly recrystallized.

The immediate hanging wall to the lower horizon (Appendix VI-3: specimen DDH FL96-33-70.5m) is made up of magnesian chlorite with alternating foliae of ferroan carbonate ± sphene and quartz-(?)plagioclase, similar to the immediate footwall.

Schists separating the upper and lower horizons (Appendix VI-3: specimens DDH FL96-33-47.6 m, 57.87 m and 59.25 m) are foliated, crenulated and locally isoclinally folded. They are made up of amphibole (possibly actinolite) and chlorite, with lesser quartz and feldspar; they locally contain biotite porphyroblasts 2-3 mm in diameter and scattered euhedral magnetite crystals up to 1 mm across. The presence of amphibole, biotite, and possibly magnesian chlorite may indicate an approach to amphibolite facies metamorphism of a mafic rock such as basalt or gabbro/diorite.

• East Kona zone - upper horizon

East Kona zone upper horizon mineralization (Figs. 12a, b) occurs above the lower horizon and is separated from it by approximately 40 to 70 m of chlorite schist. The upper horizon occurs immediately below the contact between overlying metasedimentary (unit MKcp/Unit 3) and underlying metavolcanic (unit DMF/Unit 2)

Figure 12. Kona deposit: a) schematic cross section along line D-D' in Figure 9b. b) longitudinal section of Kona west along line B-B' in Figure 9b, and c) longitudinal section of Kona east along line C-C' in Figure 9b. Figures modified from Foreman (1998).

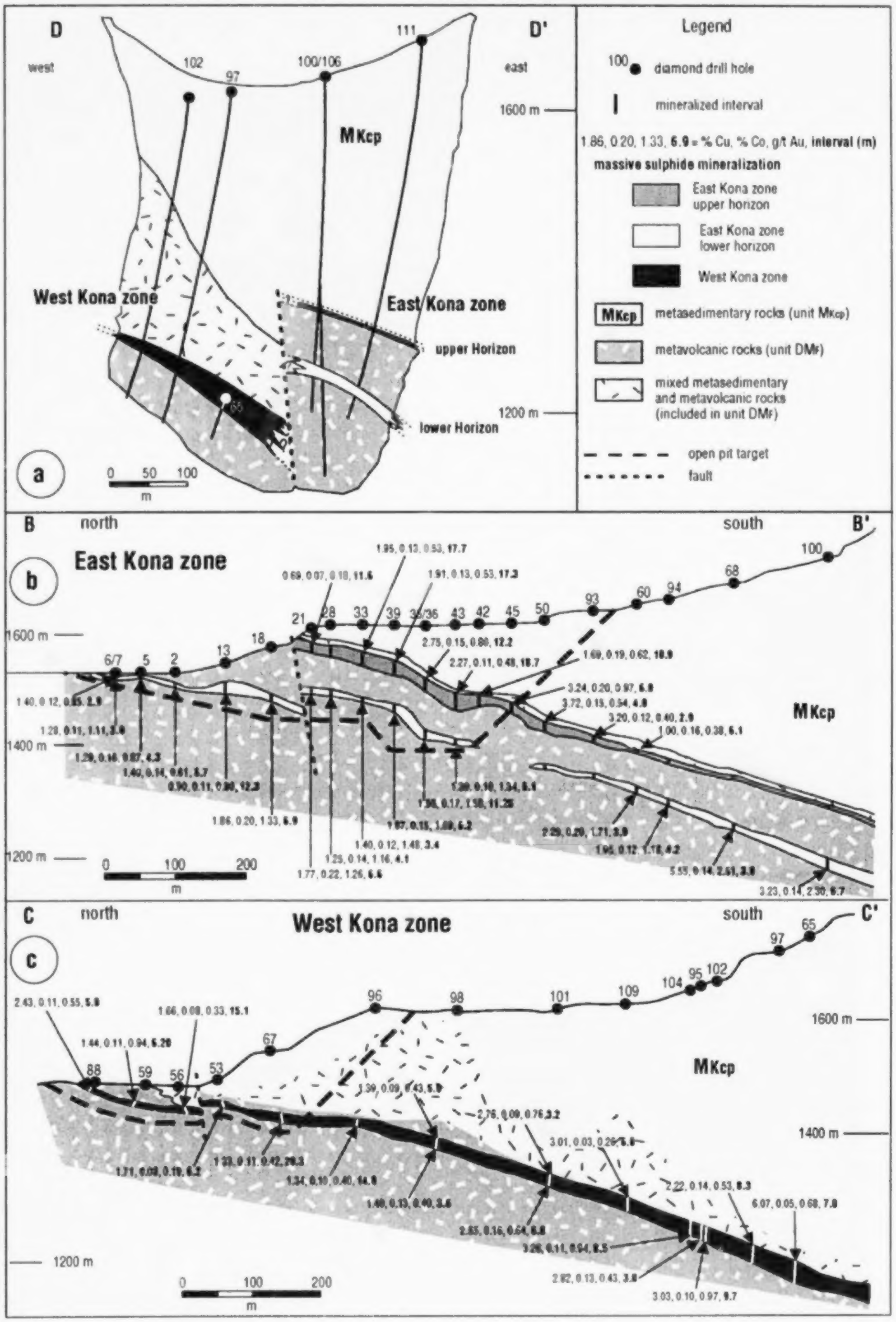
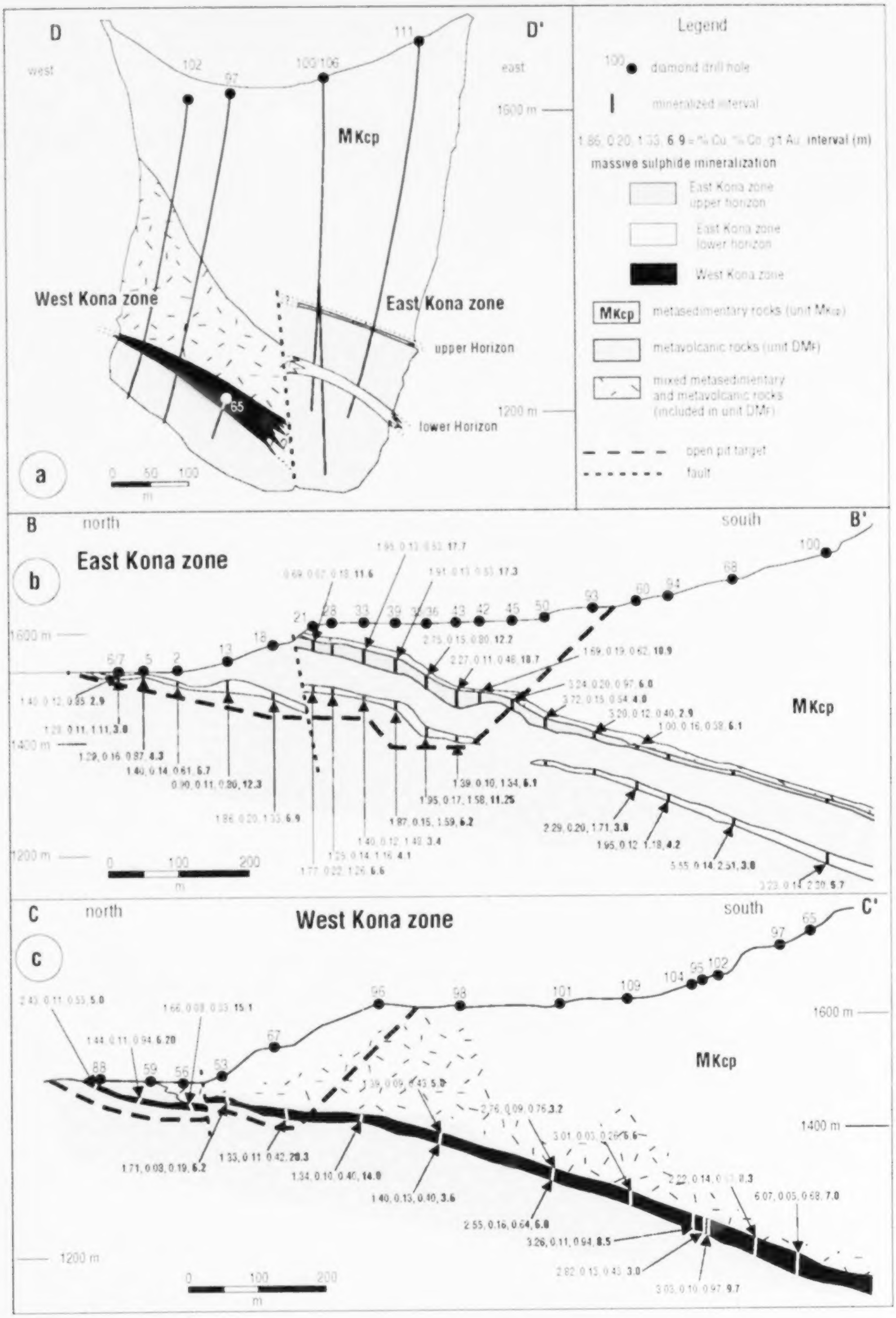

D
west
D'
east
102
97
100/106
111
MKcp
1600 m
1200 m
West Kona zone
East Kona zone
upper Horizon
lower Horizon
65
a
0 50 100
m
Legend
100 diamond drill hole
mineralized interval
1.86, 0.20, 1.33, 6.9 = % Cu, % Co, g/t Au, interval (m)
massive sulphide mineralization
East Kona zone upper horizon
East Kona zone lower horizon
West Kona zone
MKcp metasedimentary rocks (unit MKcp)
metavolcanic rocks (unit DMF)
mixed metasedimentary and metavolcanic rocks (included in unit DMF)
open pit target
fault
B
north
south
B'
East Kona zone
b
6/7 5 2 13 18 21 28 33 39 35/36 43 42 45 50 93 60 94 68 100
1600 m
1400 m
1200 m
MKcp
0 100 200
m
1.95, 0.13, 0.53, 17.7
0.69, 0.07, 0.18, 11.6
1.91, 0.13, 0.53, 17.3
2.75, 0.15, 0.80, 12.2
2.27, 0.11, 0.48, 18.7
1.69, 0.19, 0.62, 10.9
3.24, 0.20, 0.97, 6.8
3.72, 0.15, 0.54, 4.8
3.20, 0.12, 0.40, 2.9
1.00, 0.16, 0.38, 6.1
1.40, 0.12, 0.85, 2.9
1.28, 0.11, 1.11, 3.0
1.29, 0.16, 0.87, 4.3
1.40, 0.14, 0.61, 5.7
0.90, 0.11, 0.80, 12.3
1.86, 0.20, 1.33, 6.9
1.77, 0.22, 1.26, 6.6
1.25, 0.14, 1.16, 4.1
1.40, 0.12, 1.48, 3.4
1.07, 0.15, 1.09, 6.2
1.30, 0.17, 1.58, 11.25
1.20, 0.10, 1.34, 6.1
2.29, 0.20, 1.71, 3.0
1.95, 0.12, 1.18, 4.2
5.55, 0.14, 2.61, 3.0
3.23, 0.14, 2.30, 6.7
C
north
south
C'
West Kona zone
c
88 59 56 53 67 96 98 101 109 104 95 102 97 65
1600 m
1400 m
1200 m
MKcp
0 100 200
m
2.43, 0.11, 0.55, 5.8
1.66, 0.08, 0.33, 15.1
1.44, 0.11, 0.94, 5.20
1.71, 0.08, 0.19, 6.2
1.33, 0.11, 0.42, 20.3
1.34, 0.10, 0.40, 14.8
1.39, 0.09, 0.43, 5.9
1.40, 0.13, 0.40, 3.6
2.76, 0.09, 0.76, 3.2
2.65, 0.16, 0.64, 6.8
3.01, 0.03, 0.26, 5.6
3.26, 0.11, 0.94, 8.5
2.82, 0.13, 0.43, 3.8
3.03, 0.10, 0.97, 9.7
2.22, 0.14, 0.53, 8.3
6.07, 0.05, 0.68, 7.8

Figure 12. *Kona deposit:*
a) *schematic cross section along line D-D' in Figure 9b,*
b) *longitudinal section of Kona west along line B-B' in Figure 9b, and*
c) *longitudinal section of Kona east along line C-C' in Figure 9b. Figures modified from Foreman (1998).*


D
D'
west
east
102
97
100/106
111
1600 m
1200 m
MKcp
West Kona zone
East Kona zone
upper Horizon
lower Horizon
65
a
0 50 100
m
Legend
100 ● diamond drill hole
mineralized interval
1.86, 0.20, 1.33, 6.9 = % Cu, % Co, g/t Au, interval (m)
massive sulphide mineralization
East Kona zone upper horizon
East Kona zone lower horizon
West Kona zone
MKcp metasedimentary rocks (unit MKcp)
metavolcanic rocks (unit DMF)
mixed metasedimentary and metavolcanic rocks (included in unit DMF)
open pit target
fault
B
north
south
B'
b
East Kona zone
6/7
5
2
13
18
21
28
33
39
35/36
43
42
45
50
93
60
94
68
100
1600 m
1400 m
1200 m
0.69, 0.07, 0.18, 11.6
1.95, 0.13, 0.53, 17.7
1.91, 0.13, 0.53, 17.3
2.75, 0.15, 0.80, 12.2
2.27, 0.11, 0.46, 18.7
1.69, 0.19, 0.62, 10.9
3.24, 0.20, 0.97, 6.0
3.72, 0.15, 0.54, 4.0
3.20, 0.12, 0.40, 2.9
1.00, 0.16, 0.38, 6.1
MKcp
1.40, 0.12, 0.85, 2.9
1.29, 0.11, 1.11, 3.0
1.29, 0.16, 0.87, 4.3
1.40, 0.14, 0.61, 5.7
0.90, 0.11, 0.20, 12.3
1.86, 0.20, 1.33, 6.9
1.77, 0.22, 1.26, 6.6
1.25, 0.14, 1.16, 4.1
1.40, 0.12, 1.49, 3.4
1.87, 0.15, 1.59, 6.2
1.95, 0.17, 1.58, 11.25
1.39, 0.10, 1.34, 6.1
2.29, 0.20, 1.71, 3.0
1.95, 0.12, 1.18, 4.2
5.55, 0.14, 2.51, 3.0
3.23, 0.14, 2.30, 5.7
0 100 200
m
C
north
West Kona zone
south
C'
c
2.43, 0.11, 0.55, 5.0
1.66, 0.08, 0.33, 15.1
1.44, 0.11, 0.94, 6.20
88
59
56
53
67
96
98
101
109
104
95
102
97
65
1600 m
1400 m
1200 m
MKcp
1.39, 0.09, 0.43, 5.0
2.76, 0.09, 0.76, 3.2
3.01, 0.03, 0.26, 6.6
2.22, 0.14, 0.13, 8.3
6.07, 0.05, 0.68, 7.0
1.71, 0.03, 0.19, 6.2
1.33, 0.11, 0.42, 20.3
1.34, 0.10, 0.40, 14.0
1.40, 0.13, 0.40, 3.6
2.55, 0.16, 0.64, 6.0
3.26, 0.11, 0.94, 8.5
2.82, 0.13, 0.43, 3.0
3.03, 0.10, 0.97, 9.7
0 100 200
m

strata. The base of the upper horizon is evident in Kona Creek as boxwork-textured, siliceous grey to white boulders/subcrop (Figs. 13a, b). This horizon has a strike length of at least 630 m, is between 100 and 150 m wide (Foreman, 1998), and has average thicknesses of 8 to 12 m (W. Roberts, pers. comm., 1997; Deighton and Foreman, 1997); the central portion is the thickest part (Foreman, 1998). The upper horizon is fairly consistent throughout and has been divided (Foreman, 1998) into lower, middle and upper layers as described below.

The lower layer is an average of 7 m thick (maximum 17 m) and is made up dominantly of metavolcanic rocks and magnetite; the sulphide content is below 10%. Throughout the lower layer fine-grained (<1 mm) magnetite is concentrated into 1- to 10-mm-thick bands, and occurs within 2- to 20-mm-thick grey siliceous bands. The sulphides in the lower layer occur predominantly as <1- to 4-mm-long irregular wisps and blebs. The lower layer is overlain by a 3- to 8-m-thick middle layer made up of 1- to 25-cm-thick bands of sulphides and quartz within foliated dark green metavolcanic strata. The middle layer contains 30 to 60% sulphides, dominantly made up of chalcopyrite, with lesser pyrite and pyrrhotite occurring as irregular wisps and blebs. Subhedral to euhedral magnetite porphyroblasts occur throughout the surrounding metavolcanic rocks. The middle layer is overlain by a 1- to 4-m-thick upper layer made up primarily of massive, fine- to medium-grained pyrite, with 2 to 7% very fine-grained chalcopyrite and minor pyrrhotite and sphalerite.

Mineralization of the upper horizon changes to the southeast (down-plunge) where it is dominated by bands of pyrrhotite with 1 to 10% chalcopyrite in chlorite-quartz schist. In addition, the banded magnetite that underlies the upper horizon thickens locally to the southeast to a maximum of 24 m.

Petrography

Specimens of schist and massive sulphide mineralization from the East Kona zone upper horizon were examined by VanRanden (1997) and Leitch (1998; Appendix VI-3). The results are similar to those for the lower horizon and are summarized below.

An examination of specimens from two drill holes (Appendix VI-3: specimens DDH FL96-33-20.15 m and 21.38 m, FL96-34-17.6 m, 24.1 m, 20.85 m and 26.65 m) shows that in general, the three mineralized layers that make up the upper horizon are composed of pyrite, chalcopyrite, sphalerite, and locally, pyrrhotite (Fig. 13c), in a gangue of quartz-chlorite with lesser carbonate (locally ferroan) and sericite. Specimen 17.6 m contains a mix of pyrite and marcasite after pyrrhotite with "bird's eye" textures characteristic of such replacement (Leitch, 1998). Most specimens show evidence of recrystallization, however, possible relict colloform structures appear to be preserved in chalcopyrite in specimen 20.85 m.

Magnetite porphyroblasts and lesser fine-grained, anhedral, disseminated magnetite are present throughout the horizon. Garnet crystalloblasts are present locally (Fig. 13d) within chlorite schist and are partly replaced/pseudomorphed by carbonate-chlorite ± hydrobiotite (Appendix VI-3: specimens DDH FL96-34-17.6 m, 24.1 m and 26.65 m). The lower layer of the upper horizon has an increased metavolcanic content compared to the rest of the horizon and contains strongly foliated, locally kink-banded, schistose rocks (Appendix VI-3: specimens DDH FL96-33-25.8 m and 29.2 m). These rocks include chlorite schist with porphyroblasts (probably plagioclase) and carbonate pseudomorphs of former mafic crystals, and quartz-chlorite-pyrite-magnetite-minor ferroan carbonate schist with partly carbonate-sericite altered feldspar crystals and possibly relict carbonate and ferriferous biotite-altered mafic crystals. The presence of plagioclase porphyroblasts and mafic crystals suggests that at least some of the chlorite schists had an intermediate volcanic rock precursor.

All sulphide phases in the East Kona zone upper and lower horizons appear to be roughly coeval and most textures likely represent remobilization (Leitch, 1998). However, relict primary textures appear to be preserved locally. For example, there are possible relict colloform, atoll and radiating cockscomb textures in specimens DDH FL96-33-72.5 m, 73.1 m and DDH FL96-34-20.85 m (Appendix VI-3). In addition, very fine-grained pyrite with interstitial chalcopyrite/sphalerite intergrowths (e.g., specimen DDH FL96-33-21.38 m) could represent primary intergrowths of these minerals. Much of the recrystallization of pyrite and pyrrhotite from original fine-grained aggregates (e.g., Appendix VI-3: specimens DDH FL96-33-72.9 m & DDH FL96-34-20.85 m) could have occurred during ongoing hydrothermal activity at the time of sulphide deposition (Leitch, 1981a,b, 1998).

- **West Kona zone**

West Kona zone mineralization occurs immediately below the metasediment-metavolcanic contact at the same stratigraphic level as East Kona zone upper horizon mineralization, but is separated from it by a reverse fault

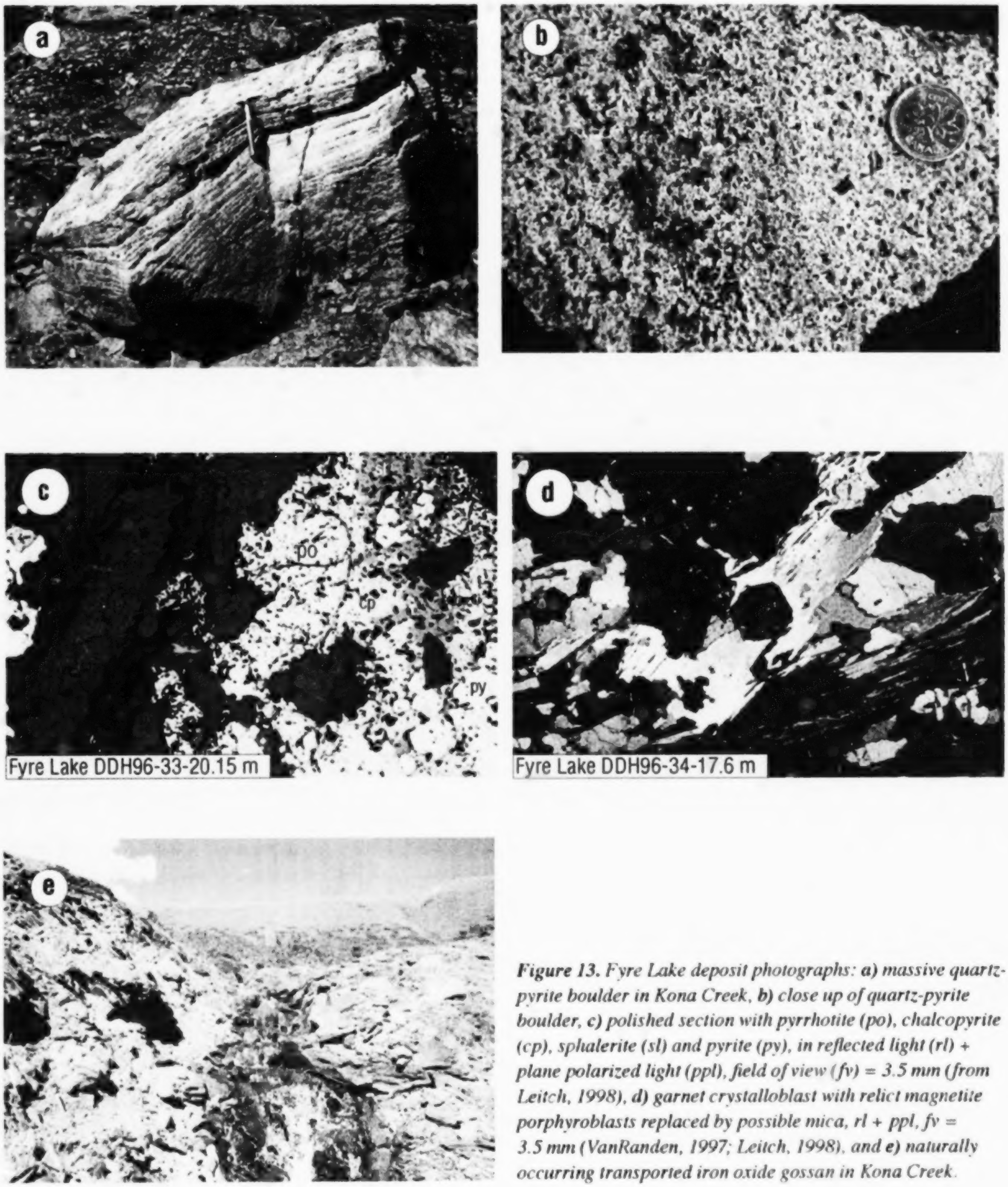


***Figure 13.** Fyre Lake deposit photographs: **a)** massive quartz-pyrite boulder in Kona Creek, **b)** close up of quartz-pyrite boulder, **c)** polished section with pyrrhotite (po), chalcopyrite (cp), sphalerite (sl) and pyrite (py), in reflected light (rl) + plane polarized light (ppl), field of view (fv) = 3.5 mm (from Leitch, 1998), **d)** garnet crystalloblast with relict magnetite porphyroblasts replaced by possible mica, rl + ppl, fv = 3.5 mm (VanRanden, 1997; Leitch, 1998), and **e)** naturally occurring transported iron oxide gossan in Kona Creek.*

(Fig. 12a). The West Kona zone has a strike length of at least 1420 m and an inferred width of 75 to 125 m (Foreman, 1998). The thickness of the mineralization varies across this width from about 44 m in the east to less than 1 m at the western margin; the thickness also varies along strike.

West Kona zone mineralization is markedly different from that of the East Kona zone in that it has dominantly siliceous gangue minerals. Greater than 80% of the West Kona zone is made up of siliceous, dominantly fine-grained, disseminated to banded magnetite, with lesser pyrite, chalcopyrite and pyrrhotite mineralization (Fig. 10e). However, it does change laterally to the west to become true massive sulphide mineralization (Foreman, 1998). In the western part of the West Kona zone, the percentage of sulphides within the zone increases to >80% and the mineralization is dominantly made up of fine- to medium-grained pyrite, with lesser fine-grained interstitial chalcopyrite and minor sphalerite, and a noticeable lack of pyrrhotite. The massive sulphides contain 1-10% quartz as blebs. At its western margin the West Kona zone is less than 1 m thick and is composed dominantly of massive pyrrhotite with about 5% blebs and fracture fillings of pyrite and chalcopyrite.

Exploration techniques

Mineralization on the Fyre Lake property was first recognized in 1960 by prospectors of Cassiar Asbestos Corporation when they discovered massive sulphide boulders (Figs. 13a, b) and iron oxide deposits (Fig. 13e) near Fire Lake and in Kona creek. However, due to extensive till cover and locally thick vegetation, the location of poorly exposed, near-surface sulphide mineralization has been guided mainly by geophysical and geochemical surveying and limited drilling (Deighton and Foreman, 1997). Geochemical and geophysical surveys in the Kona creek area identified a 3.5-km-long trend of coincident electromagnetic, magnetic and soil geochemical anomalies. Within this trend, detailed soil geochemical surveys identified several continuous and coincident copper, cobalt and zinc anomalies (copper >100 ppm, cobalt >25 ppm and zinc >200 ppm) in the area of the Kona deposit. These anomalies are spatially associated with a northwest-trending structure over 1800 m long that has been delineated by ground magnetic and horizontal loop electromagnetic (HLEM) anomalies (Blanchflower, 1997).

The Fyre Lake property, in addition to the Kona deposit, also has massive sulphide exploration targets southeast of Fire Lake in areas known as Lake and Dub (Deighton and Foreman, 1997; Yukon MINFILE, 2001, occurrences 105G 035 and 105G 036, respectively, on Figs. 4 and 5; see also Fig. 9). Several subparallel, coincident geophysical and geochemical anomalies occur over a 3-km strike length at the Lake occurrence. The Dub exploration target has coincident ground and airborne magnetic, HLEM, and local soil geochemical anomalies, but is covered by deep overburden (Yukon MINFILE, 2001).

Kudz Ze Kayah

The Kudz Ze Kayah property (Yukon MINFILE, 2001, 105G 117; 61°28'N, 130°36'W) is located near North Lakes (Fig. 14a) about 120 km southeast of the town of Ross River (Fig. 1). Base and precious metal mineralization is hosted in Mississippian felsic metavolcanic rocks (unit MK/Unit 3; Murphy, 1998; Murphy and Piercey, 1999b) as shown in Figures 3 and 4. The main mineralization, known as the ABM deposit, makes up a geological resource of 13 000 000 tonnes of 5.5% Zn, 1% Cu, 1.3% Pb, 125 g/t Ag and 1.2 g/t Au (Schultze, 1996a), including an open pit mineable resource of 11 100 000 tonnes with 5.61% Zn, 0.85% Cu, 1.56 % Pb, 136.9 g/t Ag and 1.33 g/t Au (Expatriate Resources Ltd., 2000e). New discoveries made on the Kudz Ze Kayah property include the Fault Creek zone in 1997 and the GP4F deposit in 1998, which contain inferred resources of 50 000 tonnes of 7.1% Zn, 1.0% Pb, 4.7% Cu, 130 g/t Ag, and 2.0 g/t Au and 1.5 million tonnes of 6.4% Zn, 3.1% Pb, 0.1% Cu, 89.7 g/t Ag and 2.0 g/t Au, respectively (Cominco Ltd., 1998; Expatriate Resources Ltd., 2000a).

Property geology

The Kudz Ze Kayah property is underlain by a thick, structurally transposed, polydeformed, felsic metavolcanic complex (Fig. 4), and lesser mafic metavolcanic and metasedimentary rocks, that have undergone at least mid-greenschist grade metamorphism (Mortensen and Jilson, 1985; Szybiniski, 1996; Murphy and Timmerman, 1997a, b; Murphy, 1997a, 1998).

• ABM deposit

The ABM deposit is roughly tabular and contains several thickened lenses that are collectively up to 22.5 m thick (Expatriate Resources Ltd., 1999a). The mineralization dips moderately to the north near surface and flattens at depth (Fig. 15). The deposit extends for about 700 m along strike, about 400 m down dip, and is on average about 18 m thick (Whiteway, 1995; Schultze, 1996a). Sphalerite, chalcopyrite and galena are the main economic minerals within the deposit (Fig. 14b). Electrum occurs at the margins of galena and chalcopyrite grains. The gangue includes various mixtures of magnetite, barite, pyrrhotite, pyrite and carbonate. A sample of massive sulphide mineralization (Appendix VI-3: specimen JH96-KZK) examined in polished section is composed of 65% pyrite, 15% sphalerite, 10% quartz, 6% carbonate, 3% magnetite, 1% galena, <1% muscovite and trace chalcopyrite (Fig. 14c). In the host felsic metavolcanic rocks, alteration in the hanging wall and footwall around significant sulphides is typically porphyroblastic, chlorite/biotite-ankerite-muscovite ± albite (H.C. Schultze, pers. comm., 1996). The proximal alteration is surrounded by distal carbonate-sericite-silica ± pyrite alteration.

The ABM deposit lies within a thick complex of felsic meta- tuffs and sills or flows (Figs. 14d, 16) interlayered with minor mafic sills or flows and metasedimentary rocks (Schultze, 1996a,b). It is overlain by carbonaceous phyllite (Fig. 14e), mafic metavolcanic rocks, and quartzo-feldspathic conglomerate (Murphy, 1998). The strata exhibit isoclinal recumbent folding with bedding generally sub-parallel to schistosity (Schultze, 1996b; Murphy and Timmerman, 1997a,b). The deposit has been affected by at least three phases of deformation. It parallels F_1 fold limbs, has been thickened by F_2 and imbricated by F_3 (Schultze, 1996b). Barium and base and precious metal zonation in the deposit, plus the position of proximal chloritic alteration above it, suggest that it has, at least in part, been overturned (Schultze, 1996a).

Expatriate Resources Ltd. (2000f) proposed mining the upper, moderately dipping part of the deposit using open pit mining methods. They proposed underground mining of the higher grade portions of the deeper, gently dipping part of the deposit (Fig. 15).

• GP4F deposit

The GP4F deposit is a thin massive sulphide (Fig. 14f) lens hosted by strongly altered tuffs intruded by altered and mineralized quartz-feldspar sills (Expatriate Resources Ltd., 2000a). This deposit is located about 6 km southeast of the ABM deposit and appears to be slightly lower in the stratigraphy (Fig. 4; Expatriate Resources Ltd., 1999b; Robertson, 2000). The mineralization has been traced over a 200 m strike length and 350 m down dip. The GP4F deposit is copper-poor, but lead-rich compared to the ABM deposit. It also contains significantly less selenium - 8 ppm compared to 204 ppm (Expatriate Resources Ltd., 2000a).

• Fault Creek Zone

The copper-rich Fault Creek zone consists of high-grade, near-surface mineralization. Drilling intersected 6.4 m of 5.6% Zn, 1.0% Pb, 5.2% Cu, 142 g/t Ag and 2.4 g/t Au (Expatriate Resources Ltd., 2000f). This zone is proximal to the ABM deposit, but is thought to lie at the same stratigraphic level as the GP4F deposit (Expatriate Resources Ltd., 2000a, 2001).

Exploration techniques

The ABM deposit is unexposed, however, it lies in an area with anomalous stream sediment and soil geochemistry, polymetallic sulphide float and outcrops of felsic metavolcanic rocks (Schultze, 1996a,b). Geochemical response is somewhat erratic due to thick glacial till cover (2 to 20 m) and poor soil development (Schultze, 1996a). However, a stream sediment sample (sample 105G 873215 analysed by Hornbrook and Friske, 1988) collected from a creek draining the ABM deposit returned anomalous values of Zn (1820 ppm), Mn (5460 ppm), Cu (75 ppm), Ag (0.6 ppm), Pb (102 ppm), Cd (17.4 ppm), Fe (5.31%) and Ba (1869 ppm); the same creek also returned anomalous results in a detailed regional geochemical survey (Burgert, 1997a).

The mineralization responds well to magnetic and electromagnetic surveys and the deposit is characterized by strong coincident electromagnetic and magnetic anomalies. The discovery of the GP4F deposit indicates that geophysical signatures do not need to be strong to represent significant mineralization (Expatriate Resources Ltd., 2000a). This deposit is represented by a weak airborne electromagnetic (AEM) — University of Toronto electromagnetic (UTEM) — horizontal-loop electromagnetic (HLEM) feature with a conductivity thickness of <5 Siemens (S) and a magnetic intensity of 100-200 nano-Teslas (nT) appears on one to two lines of the survey. The Fault Creek zone is defined by a weak UTEM conductor (Expatriate Resources Ltd., 2000b) and is part of a series of gravity and electromagnetic targets in the valley bottom near the Kudz Ze Kayah camp (Expatriate Resources Ltd., 2000f).

Wolverine

The Wolverine deposit (Yukon MINFILE, 2001, 105G 072; 61°25'37"N, 130°07'56"W) is located at the southeast end of Wolverine Lake about 20 km east of Kudz Ze Kayah (Figs. 1, 4, 5 and 17). The Wolverine deposit is significantly richer in zinc and precious metals

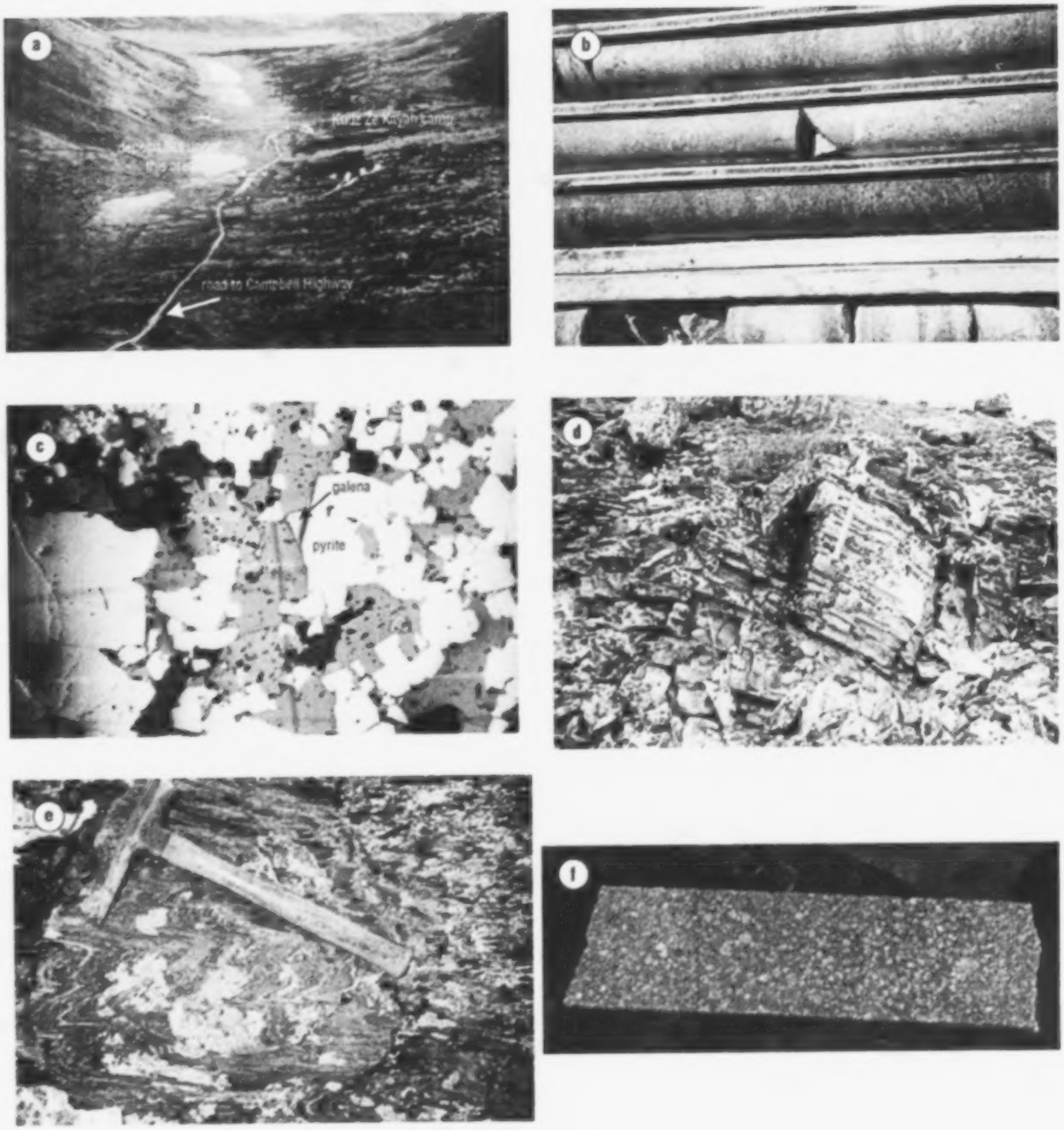

a
Kudz Ze Kayah camp
road to Campbell Highway
b
c
galena
pyrite
d
e
f

*Figure 14. Photographs for the Kudz Ze Kayah area: **a)** Kudz Ze Kayah camp and location of the deposit (looking south), **b)** massive sulphide mineralization, **c)** euhedral pyrite in a matrix of sphalerite and magnetite with minor galena, reflected light, uncrossed polars, field of view is 1.9 mm wide (Leitch, 1998), **d)** weakly deformed metarhyolite just east of Kudz Ze Kayah, **e)** strongly folded metasedimentary rocks, and **f)** massive sulphide mineralization from GP4F.*

than the Kudz Ze Kayah deposit and has a geological resource of 6.237 million tonnes grading 12.66% Zn, 1.33% Cu, 1.55% Pb, 370.9 g/t Ag and 1.76 g/t Au (Westmin Resources Limited, 1998). This includes the Lynx zone, discovered in the fall of 1996, which adjoins the western part of the main Wolverine zone (Fig. 17). Mineralization in the Lynx zone is about 6.7 m thick and has an average grade of 1.71 g/t Au, 363 g/t Ag, 1.44% Cu, 1.59% Pb and 11.84% Zn. In August, 1997, the geological inventory of Wolverine was further increased by the discovery of significant mineralization in the Sable zone, 1600 m to the southeast (Fig. 17), made up of narrow zones of high-grade massive sulphide (Westmin Resources Limited and Atna Resources Ltd., 1997; Expatriate Resources Ltd., 1999a). Exploration continued on the Wolverine property and the down-dip extension of the deposit, an extension of the Lynx zone, was encountered in drilling in June, 2000, when diamond drill hole WW00-01 intersected 7.4 m of 13.56% Zn, 1.16% Pb, 0.68% Cu, 152 g/t Ag and 0.59 g/t Au (Expatriate Resources Ltd., 2000c).

The Wolverine property, in addition to the above mineralization, also has several massive sulphide exploration targets; these include the Fisher and Puck zones. The Fisher zone occurs about 8 km northwest of the Wolverine zone (Fig. 17) and consists of numerous narrow

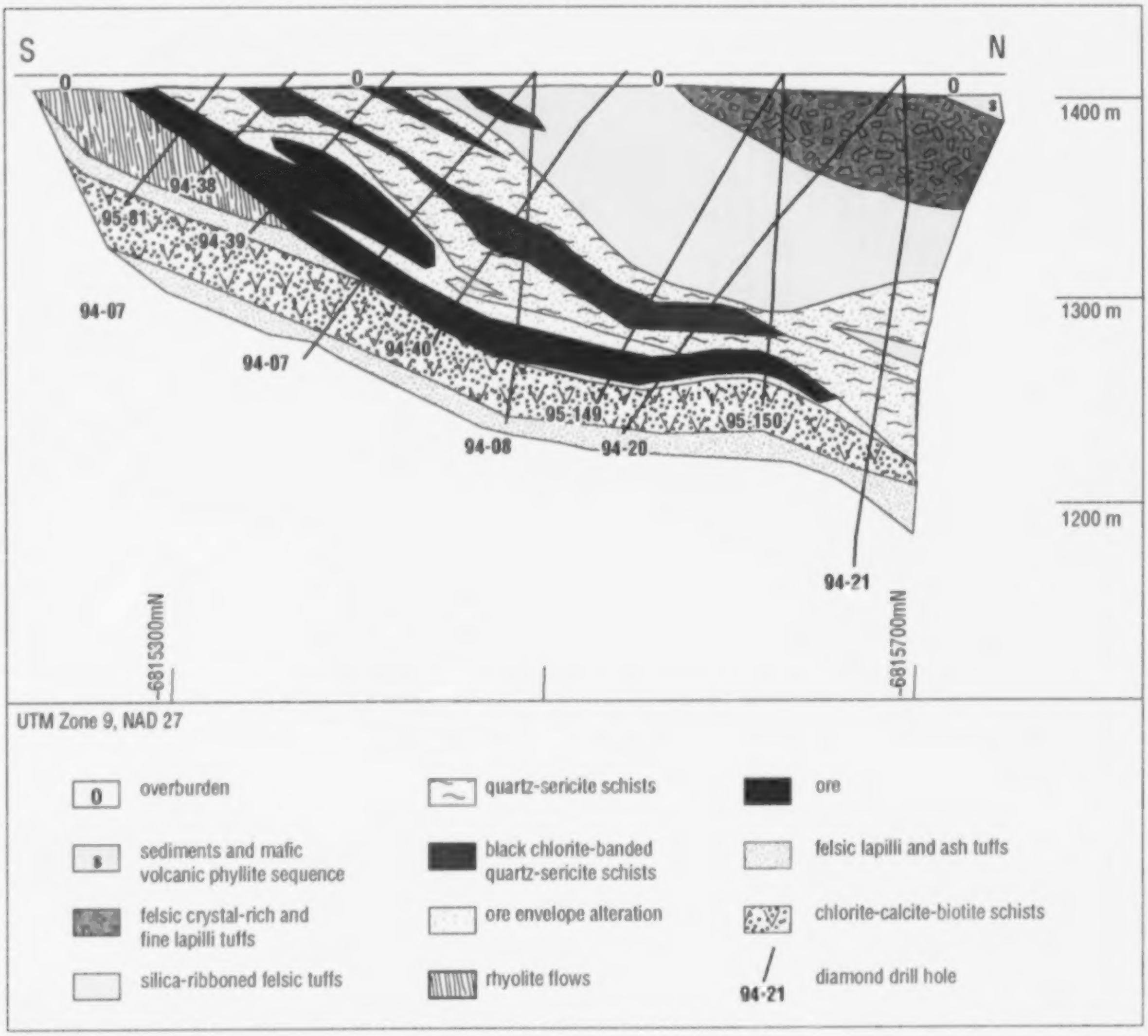

S
N
0
0
0
0
s
1400 m
1300 m
1200 m
94-38
95-81
94-39
94-07
94-07
94-40
95-149
95-150
94-08
94-20
94-21
6815300mN
6815700mN
UTM Zone 9, NAD 27
overburden
sediments and mafic volcanic phyllite sequence
felsic crystal-rich and fine lapilli tuffs
silica-ribboned felsic tuffs
quartz-sericite schists
black chlorite-banded quartz-sericite schists
ore envelope alteration
rhyolite flows
ore
felsic lapilli and ash tuffs
chlorite-calcite-biotite schists
diamond drill hole
94-21

Figure 15. Cross section through the ABM deposit, Kudz Ze Kayah property (from Schultze, 1996a).

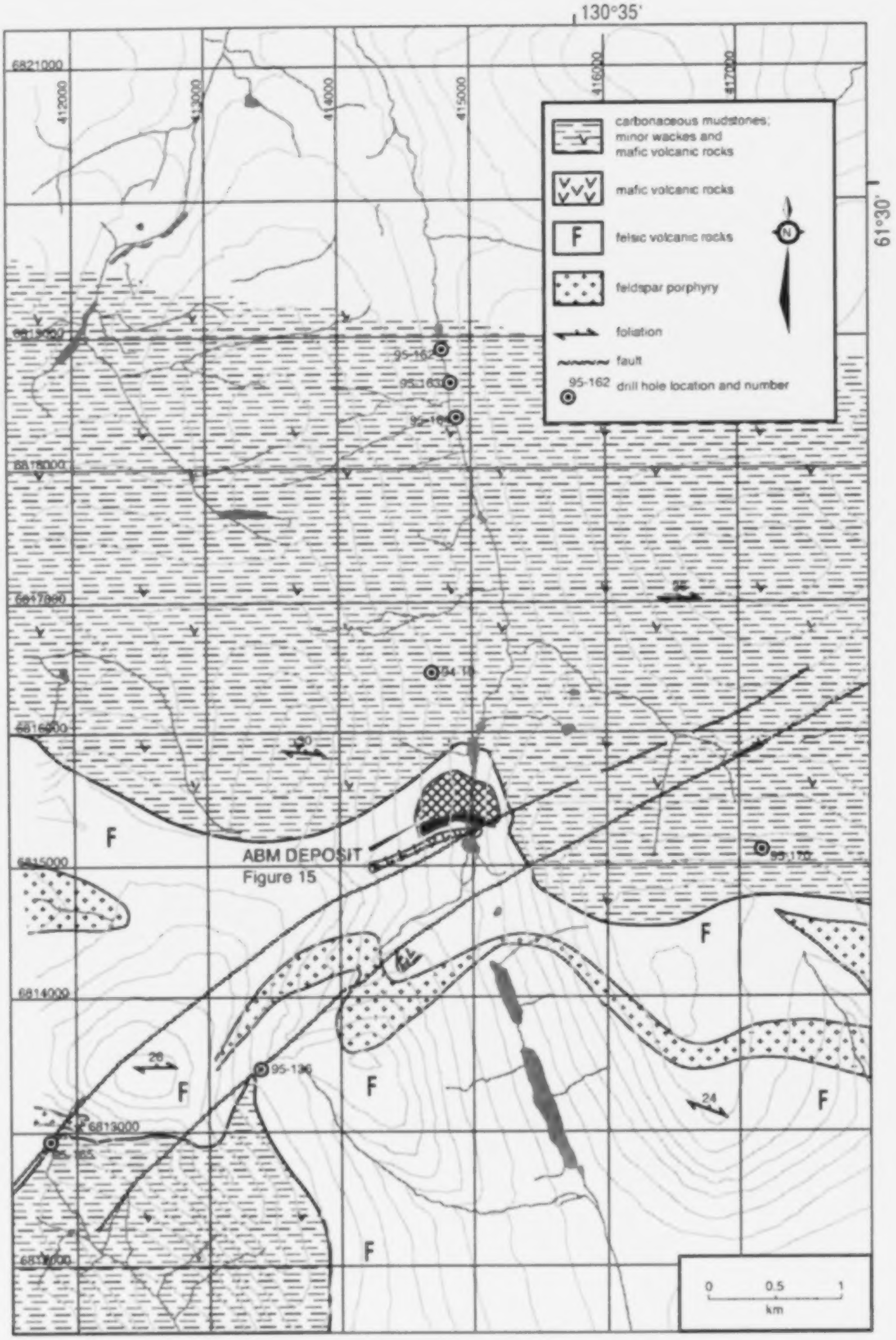

130°35'
61°30'
6821000
6819000
6818000
6817000
6816000
6815000
6814000
6813000
6812000
412000
413000
414000
415000
416000
417000
carbonaceous mudstones; minor wackes and mafic volcanic rocks
mafic volcanic rocks
F felsic volcanic rocks
feldspar porphyry
foliation
fault
95-162 drill hole location and number
N
95-162
95-163
95-164
94-19
95-170
95-136
95-165
ABM DEPOSIT
Figure 15
F
30
25
26
24
0
0.5
1
km

Figure 16. Bedrock geology map of the Kudz Ze Kayah area, NTS 105G/7 (from Schultze, 1996a); UTM Zone 9, NAD27.

sulphide bands or lenses made up of sphalerite, pyrite and minor galena in intensely altered rocks (Expatriate Resources Ltd., 1999a). Variably altered K-feldspar ± quartz-porphyritic metaintrusive rocks in this area have similarities to feldspar-quartz-phyric units in the Wolverine zone (Piercey et al., 2001). Hole 95-6 drilled in the Fisher zone intersected 2.4 m of semi-massive sulphide mineralization with grades of 0.14 g/t Au, 66.3 g/t Ag, 0.12% Cu, 1.41% Pb and 2.84% Zn (Yukon MINFILE, 2001). Follow-up drilling in 1995 and 1996 intersected low-grade mineralization over a thick interval of rhyolitic fragmental rocks.

The Puck occurrence (Yukon MINFILE, 2001, 105G 134; 61°24'31"N, 130°05'34"W) is located 2 km south of the Wolverine deposit (Fig. 17) and is underlain by rocks similar to those in the Wolverine area (Turner and Terry, 1998a, b). Rocks underlying the Puck zone include weakly altered feldspar-porphyritic metaintrusive rocks, 0.5 to 3.5 m thick, similar to those in the Wolverine, Lynx and Fisher zones (Piercey et al., 2001).

Property geology

The deposit is hosted by a thick sequence of Carboniferous rhyolitic metavolcanic rocks and carbonaceous argillite (Tucker et al., 1997; Expatriate Resources Ltd., 1999a). These rocks are part of Murphy and Piercey's (1999b) Wolverine Lake succession and are stratigraphically higher than the host rocks at Kudz Ze Kayah (Fig. 3; Schultze and Hall, 1997; Murphy and Piercey, 1999a,b). They are overlain by mafic metavolcanic and associated metasedimentary rocks of the Campbell Range succession. In the Wolverine Lake area, the host volcano-sedimentary sequence is continous over 20 km along strike. Average attitudes of foliation, which appear to parallel compositional layering, strike northwest and dip gently to moderately northeast (Murphy and Piercey, 1999a; Bradshaw et al., 2001). Drill-core- to outcrop-scale folds on the property generally verge to the southwest (ibid.) and indicate that the Wolverine deposit lies on the western limb of an open, upright structure (D.C. Murphy, pers. comm., 2000, in Bradshaw et al., 2001).

Unaltered to weakly altered porphyritic metaintrusive rocks underlie the massive sulphide mineralization and/or iron formation in the Wolverine, Lynx, Fisher, Sable and Puck zones and are not seen above them (Fig. 17; Piercey et al., 2001).

Petrography

The following summary petrographic descriptions are mainly from rocks collected in the Fisher zone (Fig. 17; see below); complete descriptions are in Appendix VI-3.

Quartz-feldspar porphyry (QFP, Appendix VI-3: specimen JH96-FZQFP) is pale grey and siliceous with an aphanitic matrix containing large white feldspar (possibly K-feldspar) crystals (or shards) up to 1 cm in diameter, and pale greenish patches, which may be sericite-altered feldspar and/or mafic crystals (Leitch, 1998). The matrix is composed of fine-grained interlocking laths of alkali feldspar and minor subhedral quartz. In hand specimen the QFP shows little to no evidence of hydrothermal alteration, however, in thin section, a well developed network of hairline sericite-quartz fractures are visible that likely represent hydrothermal alteration (ibid.).

Argillaceous rocks include quartz-eye phyllite and carbonaceous phyllite with pale blebs. The quartz-eye phyllite (Appendix VI-3: specimen JH96-FZ2) is made up of 60% sericite, 35% quartz, 2% limonite, 2% possible jarosite (after pyrite), <1% rutile, epidote and zircon, and may originally have been a felsic, fragmental volcanic rock (Leitch, 1998). Carbonaceous phyllite with pale blebs is composed mainly of quartz and sericite with lesser limonite, opaques, and siliceous, irregular-shaped, <1.5 cm blebs (possibly fragments) locally with relict plagioclase.

Rhyolitic rocks (Appendix VI-3: specimens JH96-FZ5, 7) are mainly quartz-sericite ± limonite schists (Leitch, 1998). Specimen JH96-FZ7 is made up of 90% quartz, 10% sericite and 1% or less opaques. In specimen JH96-FZ5 sericite flakes are concentrated in wispy lens- and laminar-shaped areas that may represent former fiamme, deformed fragments, or sheared-out phenocrysts; this specimen may represent strongly silicified, veined and sericitized, rhyolite (ibid.).

Rocks of possible exhalative origin, in the Fisher zone, are interlayered with the metarhyolite and include quartz-pyrite (Appendix VI-3: specimens JH96-FZ8, 11) and barite-magnetite (Appendix VI-3: specimen JH96-FZ10) rock. Quartz-pyrite rock consists of brecciated to strongly deformed quartz in a matrix of, or with folia of sericite-(?) clay and pyrite pseudomorphs (ibid.). Barite-magnetite rock is finely laminated and fine-grained with 20% barite in layers up to 0.5 cm thick, 15% magnetite, minor goethite, green biotite, hydrobiotite and rare pyrite, mixed with 65% quartz. Similar rock occurs as iron formation in the Wolverine zone (Appendix VI-3: specimen JH96-WOLV4).

Deposit geology

Wolverine deposit geology has been described in detail by Baknes and Weber (1996) and Bradshaw et al. (2001). The footwall to the deposit is made up of tuffaceous carbonaceous phyllite and quartz 'eye'-bearing phyllite 30 to 50 m thick overlain by felsic metavolcaniclastic rocks 1 to 60 m thick that are interlayered with variable amounts of carbonaceous argillite (Unit 1 in Figs. 18, 19; Bradshaw et al., 2001). The footwall also contains K-feldspar-phyric metaporphyry sills up to 15 m thick that generally occur about 20 m below the massive sulphide horizon.

Massive sulphide mineralization typically lies immediately above, or locally within, the felsic metavolcaniclastic rocks in an 85- to 160-m-thick sequence of interlayered carbonaceous argillite and felsic metavolcanic flow (Fig. 20a) and tuffaceous units with carbonate-pyrite and magnetite iron formation (Fig. 20b) exhalative horizons (Unit 2 in Figs. 18, 19; Tucker et al., 1997; Expatriate Resources Ltd., 1999a; Bradshaw et al., 2001). The mineralized interval occurs at the contact between underlying feldspar-quartz-porphyritic rhyolitic metavolcaniclastic rocks and overlying massive aphyric metarhyolite, and is interlayered with black, carbonaceous, slightly tuffaceous argillite (Expatriate Resources Ltd., 1999a; Bradshaw et al., 2001). The footwall contact is gradational (Westmin Resources Limited, 1996). Locally,

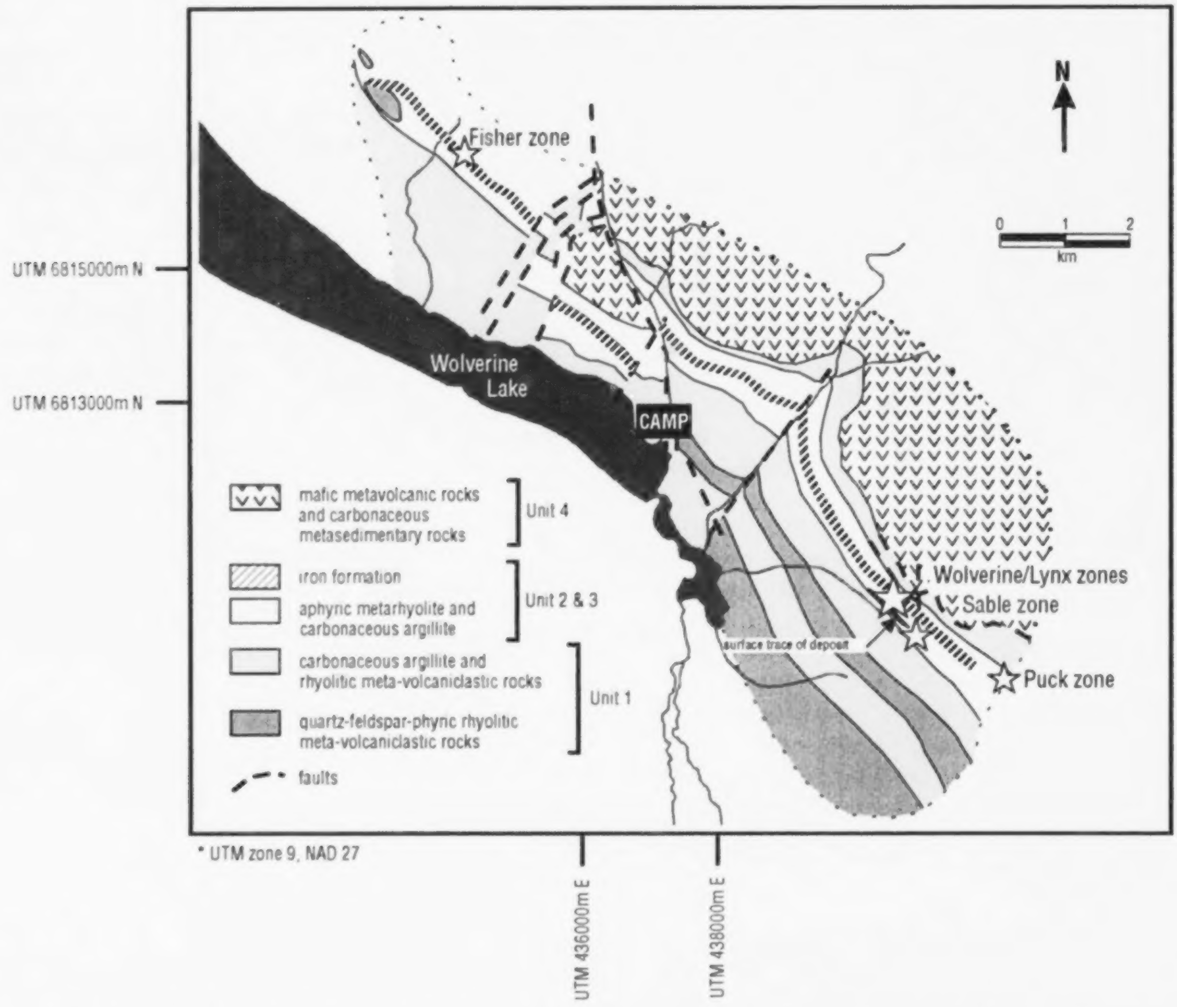

Fisher zone
N
0
1
2
km
UTM 6815000m N
UTM 6813000m N
Wolverine Lake
CAMP
Wolverine/Lynx zones
Sable zone
surface trace of deposit
Puck zone
mafic metavolcanic rocks and carbonaceous metasedimentary rocks
Unit 4
iron formation
aphyric metarhyolite and carbonaceous argillite
Unit 2 & 3
carbonaceous argillite and rhyolitic meta-volcaniclastic rocks
quartz-feldspar-phyric rhyolitic meta-volcaniclastic rocks
Unit 1
faults
* UTM zone 9, NAD 27
UTM 436000m E
UTM 438000m E

Figure 17. Map of the Wolverine property showing the location of the Wolverine, Lynx, Sable, Fisher and Puck zones (modified from Atna Resources Ltd., 1999). Unit numbers approximate those units used in Figures 18 and 19.

argillite forms the immediate hanging wall and is in sharp contact with the massive sulphide mineralization. Magnetite iron formation occurs as two 1- to 10-m-thick horizons about 80 m upsection from the massive sulphide horizon (Bradshaw et al., 2001). The magnetite iron formation horizons are laterally extensive (up to 12 km along strike) and serve as regional stratigraphic markers (Tucker et al., 1997; Bradshaw et al., 2001). Local, 1- to 10-m-thick carbonate-pyrite exhalite occurs below the magnetite iron formation horizons and is thickest over the deposit.

The upper magnetite iron formation is overlain by approximately 80 m of fragmental metarhyolite and carbonaceous argillite that contains metarhyolite clasts (Unit 3 in Figs. 18, 19; Bradshaw et al., 2001). This unit is, in turn, overlain by at least 200 m of metabasalt flow and volcaniclastic rocks[10] interlayered with carbonaceous metasedimentary rocks (Unit 4 in Figs. 18, 19; Bradshaw et al., 2001).

Mineralization

The Wolverine deposit is made up of two thick lenses of stratiform massive sulphide mineralization known as the Wolverine and Lynx zones separated by an area of semi-massive sulphide mineralization and sulphide-stringer mineralization known as the Hump zone (Figs. 20c, d, 21; Bradshaw et al., 2001). In general, the deposit dips 35° to 50° to the northeast (Fig. 19) and has been defined over a strike length of 700 m and a down-dip width of 400 m.

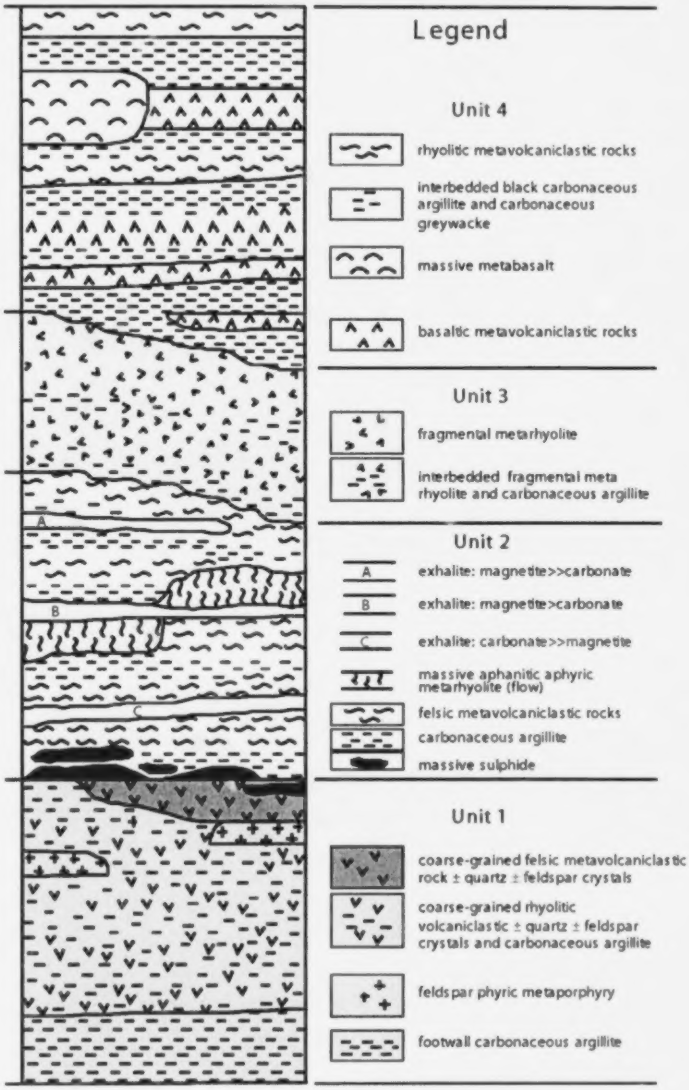

A
B
C
Legend
Unit 4
rhyolitic metavolcaniclastic rocks
interbedded black carbonaceous argillite and carbonaceous greywacke
massive metabasalt
basaltic metavolcaniclastic rocks
Unit 3
fragmental metarhyolite
interbedded fragmental meta rhyolite and carbonaceous argillite
Unit 2
A
exhalite: magnetite>>carbonate
B
exhalite: magnetite>carbonate
C
exhalite: carbonate>>magnetite
massive aphanitic aphyric metarhyolite (flow)
felsic metavolcaniclastic rocks
carbonaceous argillite
massive sulphide
Unit 1
coarse-grained felsic metavolcaniclastic rock ± quartz ± feldspar crystals
coarse-grained rhyolitic volcaniclastic ± quartz ± feldspar crystals and carbonaceous argillite
feldspar phyric metaporphyry
footwall carbonaceous argillite

Figure 18. *Generalized stratigraphic section for the Wolverine deposit (from Bradshaw et al., 2001).*

Polymetallic massive sulphide lenses are made up of pyrite and sphalerite with lesser chalcopyrite, pyrrhotite, galena, silver-rich tetrahedrite-tennantite and arsenopyrite (Tucker et al., 1997; Expatriate Resources Ltd., 1999a; Bradshaw et al., 2001). Ore minerals occur either interstitial to pyrite or as a matrix to disseminated pyrite. Gangue minerals include quartz, calcite, dolomite, ankerite, siderite, chlorite and sericite (Tucker et al., 1997; Bradshaw et al., 2001). Individual sulphide lenses vary in thickness from a maximum of 9.8 m in the Wolverine zone to less than 1 m on the fringes of the deposit (Bradshaw et al., 2001). Locally, there are multiple stacked lenses, for example in the thickest sections of the Lynx zone, separated by 4 to 8 m of host rock (Bradshaw et al., 2001). The stratiform sulphide lenses are generally fine- to medium-grained and display millimetre- to centimetre-scale banding, and clastic and replacement textures (Tucker

[10] Originally included in Campbell Range succession (Murphy and Pearcey, 1999b). Now considered part of the Wolverine Lake succession (Bond et al., 2002).

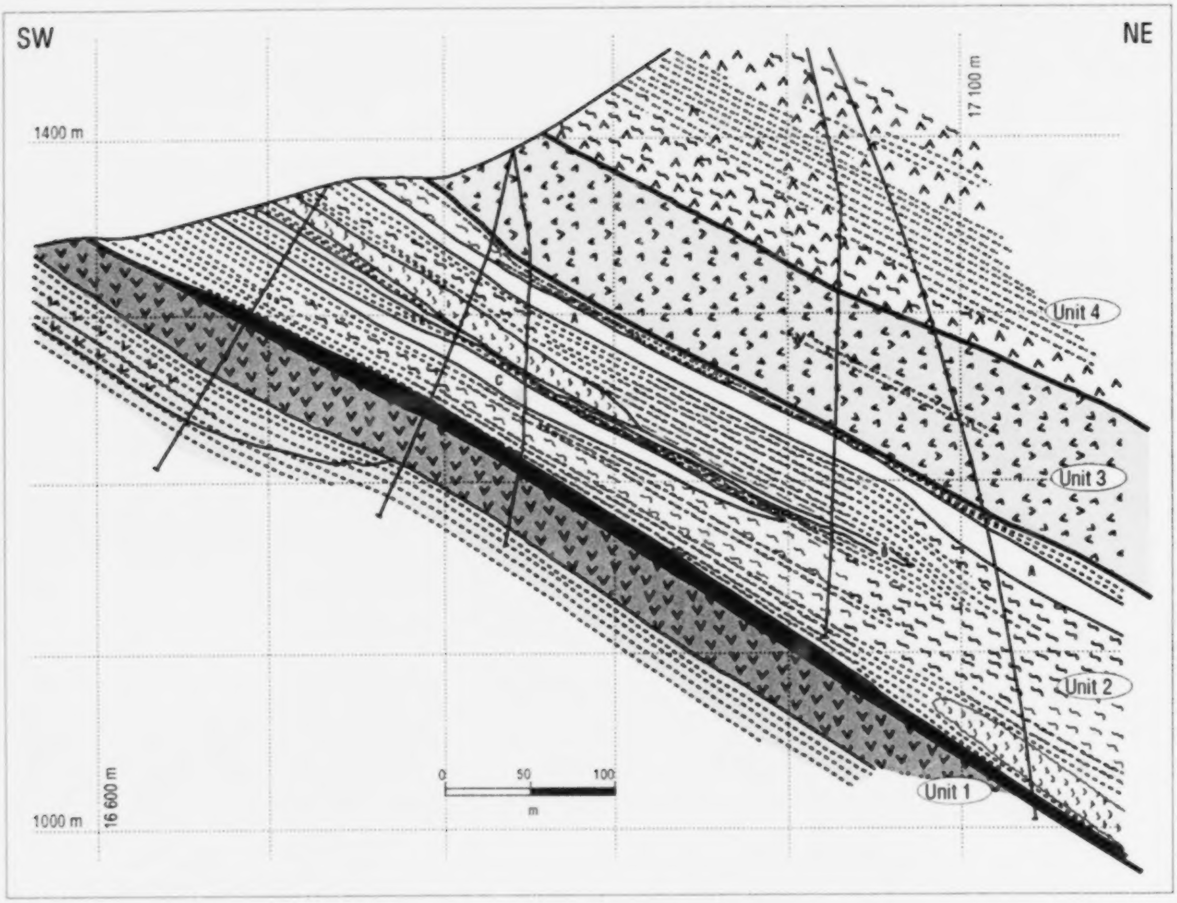


Figure 19. *Geological cross section 16700E through the Wolverine zone (after Bradshaw et al., 2001). The location of this cross section is shown on Figure 21. Unit numbers and patterns are the same as those of Figure 18.*

et al., 1997; Bradshaw et al., 2001). Pyrite occurs as very fine-grained anhedral masses and as porphyroblasts (Bradshaw et al., 2001). Fine-grained, red-brown sphalerite forms wispy, sub-millimetre- to centimetre-scale layers giving the mineralization a banded appearance. In most places the layers are parallel to the dominant foliation. Locally, sphalerite occurs interstitial to massive pyrite. Galena, tetrahedrite-tennantite and arsenopyrite typically occur together as fine-grained aggregates within sphalerite-rich layers (Bradshaw et al., 2001). Chalcopyrite is rare within the massive sulphide lenses and occurs as remobilized medium-grained masses on the edges of quartz or wall- rock fragments, except in the northwest portion of the Lynx zone where 1.3-m-thick chalcopyrite-rich massive sulphide mineralization forms the base of the zone (Bradshaw et al., 2001). Primary breccia textures are preserved on the eastern flank of the Lynx zone at the top of, and within, the massive sulphide lens (Bradshaw et al., 2001). Matrix-supported breccia is made up of 3- to 5-mm-diameter rounded clasts of fine-grained pyrite in a matrix of fine-grained pyrite. Clast-supported breccia is made up of angular clasts of pyrite and sphalerite one to several centimetres across in a pyrite matrix.

Replacement mineralization, defined by Bradshaw et al. (2001) as areas where sulphide minerals appear to have partly to completely replaced host rock, occurs in the immediate footwall to the Wolverine and Lynx zones, and in the Hump zone. Replacement mineralization is made up dominantly of chalcopyrite and sphalerite with lesser pyrite. In general, replacement mineralization occurs as discrete, fine-grained, semi-massive sulphide zones several centimetres to 1 m thick surrounding stringer-mineralization. However, locally it forms significant thicknesses of semi-massive sulphide mineralization. For example, in the Hump zone replacement mineralization is up to 13 m thick and beneath the Wolverine zone it is about 7 m thick.

Stringer mineralization is well developed in several areas of the deposit, for example beneath and within replacement mineralization in the Hump zone, and in the immediate footwall to the Wolverine zone (Bradshaw et al., 2001). Stringer mineralization in these areas is made up of randomly oriented 2- to 3-cm-wide quartz-pyrite-chalcopyrite-sphalerite ± pyrrhotite veins. Where stringer mineralization is less well developed lower in the footwall it is made up of 0.5- to 1-cm-wide quartz-sulphide veins that lack significant alteration envelopes.

Zonation

Combined metal grades illustrate metal zoning within the Wolverine deposit (Bradshaw et al., 2001). In general, zinc and lead are concentrated in the stratiform massive sulphide mineralization on the fringes of the deposit, and copper is concentrated in the central part of the deposit in replacement and stringer-vein mineralization. However, metal distribution, especially for precious metals, is variable within the massive sulphide mineralization.

Hydrothermal alteration

Sericite alteration is the dominant style of hydrothermal alteration associated with the Wolverine deposit, with lesser chlorite, silica and carbonate alteration (Bradshaw et al., 2001). Sericite alteration occurs in fine- to coarse-grained felsic metavolcaniclastic rocks mainly in the footwall. These rocks contain 40 to 60% sericite and are intensely foliated. In the most strongly altered zones

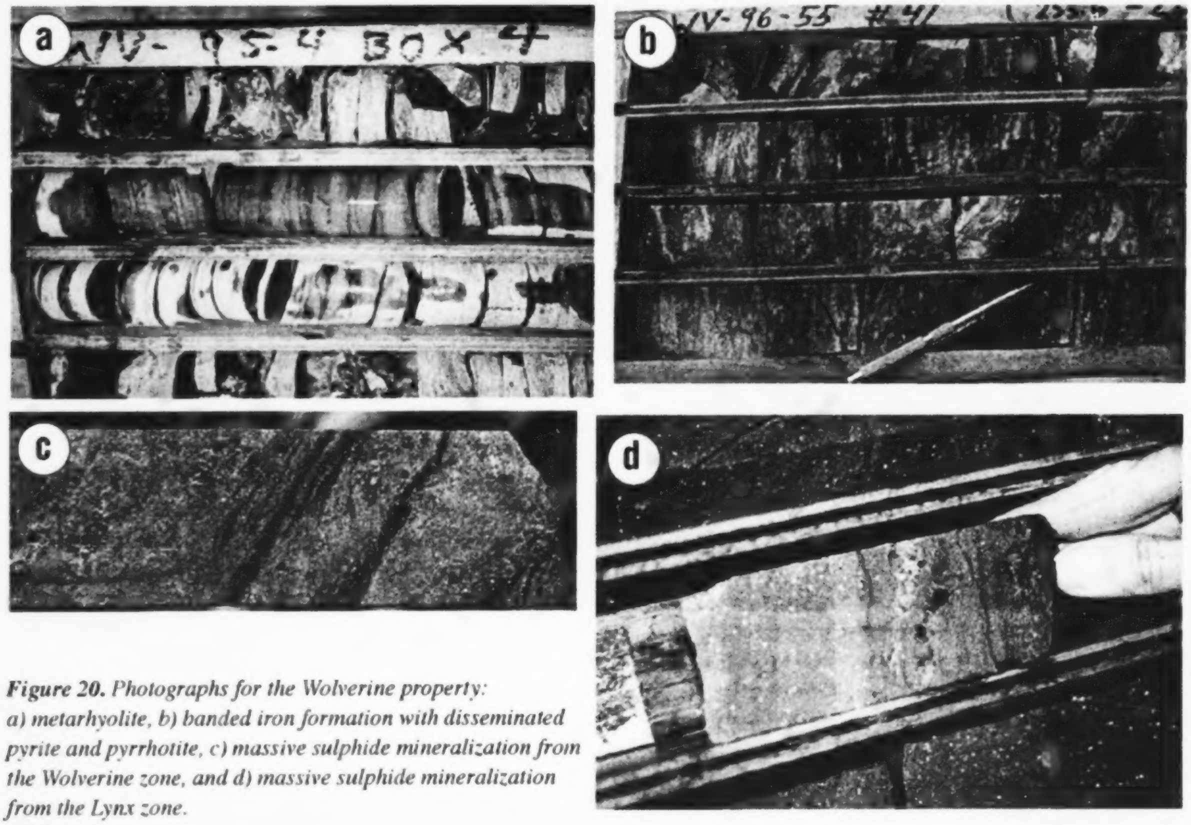


Figure 20. *Photographs for the Wolverine property: a) metarhyolite, b) banded iron formation with disseminated pyrite and pyrrhotite, c) massive sulphide mineralization from the Wolverine zone, and d) massive sulphide mineralization from the Lynx zone.*

all minerals except quartz have been replaced by sericite. Sericite alteration is best developed in the Wolverine and Hump zones where it is up to 50 m thick. Sericite alteration is less well developed in the Lynx zone. Sericite alteration locally occurs in the hanging wall where the massive sulphide mineralization is hosted by metavolcaniclastic rocks (Unit 1 on Figs. 18 and 19).

There is a gradual transition, in most localities, from sericite alteration to chlorite alteration with increasing proximity to the mineralization (Bradshaw et al., 2001). Chlorite alteration is best developed in the Wolverine zone, in the immediate footwall to the massive sulphide mineralization, and in association with replacement-style mineralization in the Hump zone. Carbonate alteration, characterized by the development of calcite, ankerite and siderite porphyroblasts up to 2 cm in diameter, is commonly associated with chlorite alteration (Bradshaw et al., 2001). Silica alteration is rare and is confined to narrow zones immediately adjacent to quartz-sulphide veins (Bradshaw et al., 2001). Locally, carbonaceous phyllite in the hanging wall is strongly silicified and contains quartz-pyrite veinlets.

Interpretation

Metal distribution indicates the mineralization may be related to a fissure-type vent (Bradshaw et al., 2001). For example, in the copper-rich Hump zone there are extreme variations in sulphide thicknesses over short distances suggesting that the zone may be spatially related to an inferred growth fault that likely localized the ascent of mineralizing fluids. In addition, the concentration of intrusions and flow rocks proximal to the Wolverine deposit implies that the emplacement of intrusions was also likely controlled by structures (Piercey et al., 2001).

The intrusions may have been heat and/or metal sources (Piercey et al., 2001). However, compared to other VMS districts where subvolcanic intrusions are considered to be heat sources (for example, Noranda, Mattabi, Mount Read; cf. Galley, 1996; cf. Large et al., 1996) the intrusions underlying the Wolverine deposit are volumetrically minor and their size was probably insufficient to have generated the hydrothermal flux required to form the deposit. Piercey et al. (2001) suggest that the intrusions may be apophyses of a larger, as yet unidentified, intrusive system that may have controlled the hydrothermal budget of the Wolverine deposit.

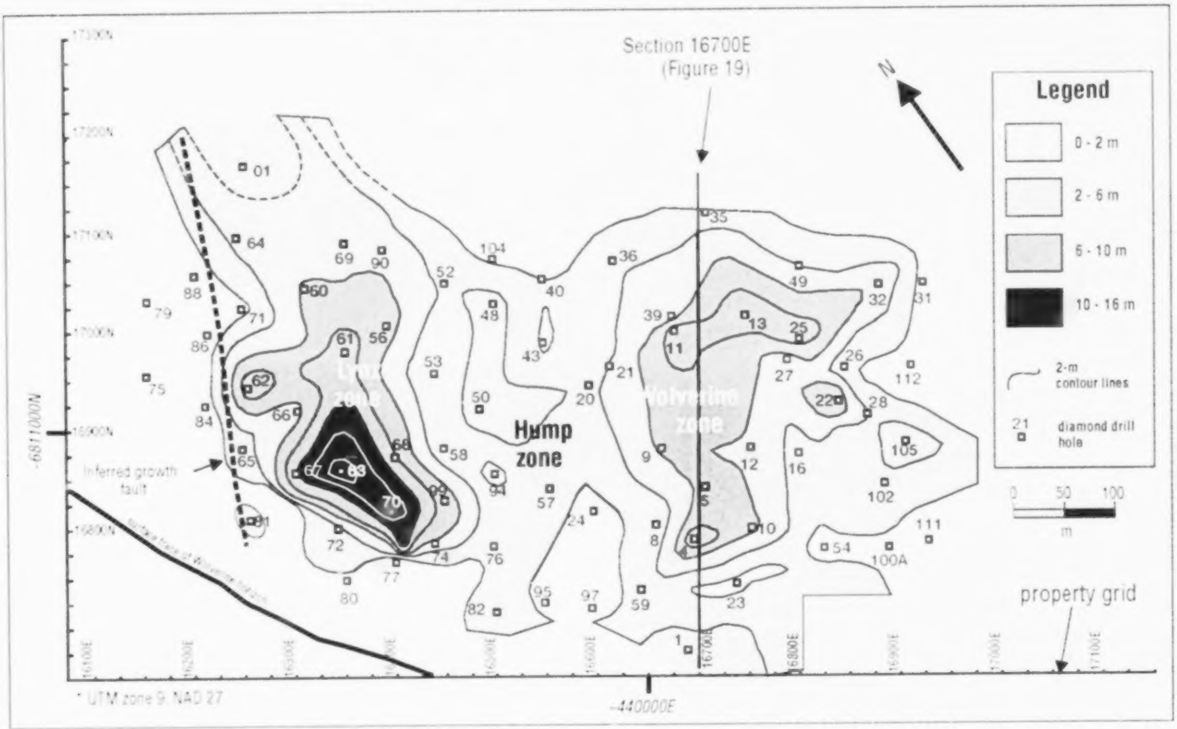

Section 16700E
(Figure 19)
N
Legend
0 - 2 m
2 - 6 m
6 - 10 m
10 - 16 m
2-m contour lines
21 diamond drill hole
0 50 100
m
17300N
17200N
17100N
17000N
16900N
16800N
-6811000N
Inferred growth fault
Lynx zone
Hump zone
Wolverine zone
01
64
69
90
104
52
40
36
35
49
32
31
88
79
71
60
48
39
13
25
11
86
61
56
43
53
27
26
112
75
62
21
50
20
22
28
84
66
105
65
68
58
9
12
16
67
63
94
57
5
102
70
99
24
8
10
111
81
72
74
76
54
100A
77
80
95
97
59
23
82
1
16100E
16200E
16300E
16400E
16500E
16600E
16700E
16800E
16900E
17000E
17100E
property grid
* UTM zone 9, NAD 27
-440000E

Figure 21. *Surface projection of true thickness contours of massive sulphide mineralization (Bradshaw et al., 2001). Locations of drill holes are projected to the base of the massive sulphide intersections. Coordinates (in metres) are from the property grid.*

all minerals except quartz have been replaced by sericite. Sericite alteration is best developed in the Wolverine and Hump zones where it is up to 50 m thick. Sericite alteration is less well developed in the Lynx zone. Sericite alteration locally occurs in the hanging wall where the massive sulphide mineralization is hosted by metavolcaniclastic rocks (Unit 1 on Figs. 18 and 19).

There is a gradual transition, in most localities, from sericite alteration to chlorite alteration with increasing proximity to the mineralization (Bradshaw et al., 2001). Chlorite alteration is best developed in the Wolverine zone, in the immediate footwall to the massive sulphide mineralization, and in association with replacement-style mineralization in the Hump zone. Carbonate alteration, characterized by the development of calcite, ankerite and siderite porphyroblasts up to 2 cm in diameter, is commonly associated with chlorite alteration (Bradshaw et al., 2001). Silica alteration is rare and is confined to narrow zones immediately adjacent to quartz-sulphide veins (Bradshaw et al., 2001). Locally, carbonaceous phyllite in the hanging wall is strongly silicified and contains quartz-pyrite veinlets.

Interpretation

Metal distribution indicates the mineralization may be related to a fissure-type vent (Bradshaw et al., 2001). For example, in the copper-rich Hump zone there are extreme variations in sulphide thicknesses over short distances suggesting that the zone may be spatially related to an inferred growth fault that likely localized the ascent of mineralizing fluids. In addition, the concentration of intrusions and flow rocks proximal to the Wolverine deposit implies that the emplacement of intrusions was also likely controlled by structures (Piercey et al., 2001).

The intrusions may have been heat and/or metal sources (Piercey et al., 2001). However, compared to other VMS districts where subvolcanic intrusions are considered to be heat sources (for example, Noranda, Mattabi, Mount Read; cf. Galley, 1996; cf. Large et al., 1996) the intrusions underlying the Wolverine deposit are volumetrically minor and their size was probably insufficient to have generated the hydrothermal flux required to form the deposit. Piercey et al. (2001) suggest that the intrusions may be apophyses of a larger, as yet unidentified, intrusive system that may have controlled the hydrothermal budget of the Wolverine deposit.

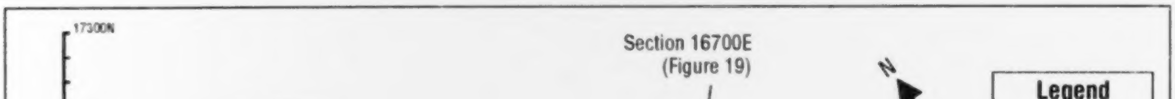

Section 16700E
(Figure 19)
N
Legend
0 - 2 m
2 - 6 m
6 - 10 m
10 - 16 m
2-m contour lines
21 diamond drill hole
0 50 100
m
Lynx zone
Hump zone
Wolverine zone
Inferred growth fault
Surface trace of Wolverine horizon
property grid
17300N
17200N
17100N
17000N
16900N
16800N
16100E
16200E
16300E
16400E
16500E
16600E
16700E
16800E
16900E
17000E
17100E
-6811000N
-440000E
* UTM zone 9, NAD 27

Figure 21. Surface projection of true thickness contours of massive sulphide mineralization (Bradshaw et al., 2001). Locations of drill holes are projected to the base of the massive sulphide intersections. Coordinates (in metres) are from the property grid.

Exploration techniques

The original Foot claims (Wolverine property) were staked in 1993 to cover a mineral occurrence listed in the Yukon MINFILE database that was contained in strata considered favourable for hosting VMS mineralization.

Geochemical and geophysical techniques have been used with success at Wolverine. Most samples collected proximal to Wolverine Lake during a regional stream sediment sampling program returned elevated levels of zinc and barium with some specimens containing elevated levels of copper, lead, silver, molybdenum, cadmium and/or uranium, and rarely gold. These samples were from creeks with neutral to alkaline pHs (Hornbrook and Friske, 1988). Drift prospecting in this area also identified anomalous levels of gold, silver, arsenic, copper, lead and zinc in the clay size fraction of till (Fig. 8; Plouffe, 1989).

The Wolverine deposit is marked by coincident moderate to highly anomalous Cu-Pb-Zn ± Ba ± Ag ± Au ± Mo soil geochemical anomalies (Fig. 22; Atna Resources Ltd., 1999). The Fisher zone has anomalous Cu, Pb, Zn, Ag, Au and Ba values in soil and silt (Expatriate Resources Ltd., 1999a), however absolute concentrations are lower than in the Wolverine area.

Airborne and ground magnetic surveys outlined the laterally extensive banded iron formation (Yukon MINFILE, 2001). The Puck claims were staked to cover the southeast extension of a regional aeromagnetic anomaly that is associated with the Wolverine deposit. The carbon content of argillite in the Wolverine area makes it highly conductive, and thus, complicates the interpretation of electromagnetic results. The response of the argillite may potentially mask the response of sulphides or conversely provide misleading anomalies.

Wolverine and Kudz Ze Kayah metallurgy

Combined development of the Wolverine and Kudz Ze Kayah properties has been proposed (cf. Expatriate Resources Ltd. 1999b, 2000a, d). Preliminary metallurgical test results indicate that Wolverine mineralization can be mixed with that from Kudz Ze Kayah (op. cit.). This gives a resource of 14.57 million tonnes grading 7.23% Zn, 1.53% Pb, 0.97% Cu, 184.5 g/t Ag and 1.43 g/t Au (Expatriate Resources Ltd., written communication, 2001). Based on a mill feed ratio of 3000 tonnes per day from an open pit mine at Kudz Ze Kayah and 1250 tonnes per day from an underground mine

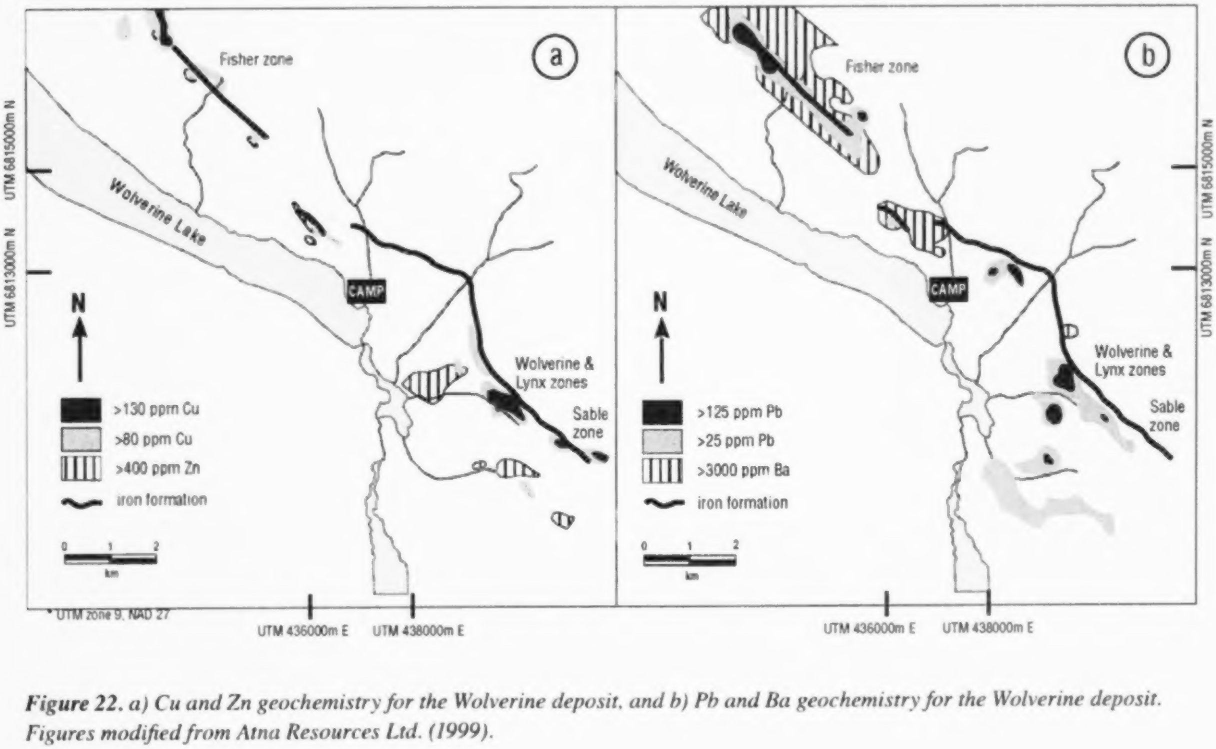

a
Fisher zone
Wolverine Lake
CAMP
N
Wolverine & Lynx zones
Sable zone
>130 ppm Cu
>80 ppm Cu
>400 ppm Zn
iron formation
0 1 2
km
UTM 6813000m N
UTM 6815000m N
UTM zone 9, NAD 27
UTM 436000m E
UTM 438000m E
b
Fisher zone
Wolverine Lake
CAMP
N
Wolverine & Lynx zones
Sable zone
>125 ppm Pb
>25 ppm Pb
>3000 ppm Ba
iron formation
0 1 2
km
UTM 6813000m N
UTM 6815000m N
UTM 436000m E
UTM 438000m E

Figure 22. a) Cu and Zn geochemistry for the Wolverine deposit, and b) Pb and Ba geochemistry for the Wolverine deposit. Figures modified from Atna Resources Ltd. (1999).

at Wolverine, the operation would produce an average of 40 300 tonnes of precious metal-rich copper concentrate (2.5% Zn, 1.8% Pb, 25% Cu, 4350 g/t Ag, 16 g/t Au), 32 600 tonnes of lead concentrate (6.2% Zn, 55% Pb, 1.4% Cu, 2000 g/t Ag, 35 g/t Au) and 201 700 tonnes of zinc concentrate (55% Zn, 1.5% Pb, 0.3% Cu, 120 g/t Ag, 0.8 g/t Au) annually using conventional flotation techniques (Expatriate Resources Ltd., 2000d). Tests indicate that Zn, Pb, Cu, Ag and Au recoveries will be 91%, 64%, 81%, 85% and 73%, respectively (ibid.). The ores would be blended during crushing and processed in a mill facility (Fig. 23) located at Kudz Ze Kayah. The sulphide concentrates could then be trucked to Skagway, Alaska, and shipped from there to smelters in Canada and Asia.

Metallurgical tests also indicate that there are high levels of selenium in all sulphide minerals within the ore from Wolverine; the highest levels occur in lead-sulphide and sulphosalt minerals (Atna Resources Ltd., 1999; Expatriate Resources Ltd., 1999a). Initial copper and zinc concentrates produced from the Wolverine deposit had average selenium contents of 0.43% and 0.15%, respectively, which are several times the levels normally found in similar concentrates (Atna Resources Ltd., 1999; Expatriate Resources Ltd., 1999a). However, blending ore from Wolverine with ore from Kudz Ze Kayah would reduce the selenium content to levels acceptable to several smelters (Expatriate Resources Ltd., 2000e). Therefore, the copper and zinc concentrates could be acceptable as produced, which would significantly reduce mine development capital costs (ibid.)

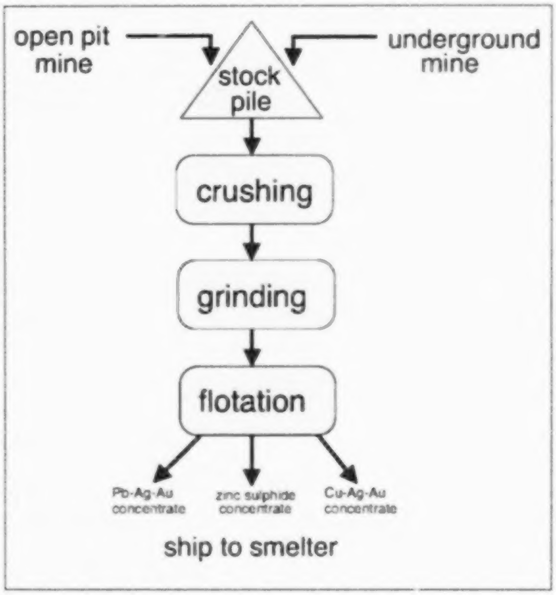


Figure 23. *General process flowsheet for ore from the Kudz Ze Kayah and Wolverine deposits (modified from Expatriate Resources Ltd., 2000a).*

Roasting test work on the combined Wolverine-Kudz Ze Kayah zinc sulphide concentrate has shown that 96% of the selenium can be removed by a single-stage roast at 800-900°C if necessary; this process also produced a cleaner, lighter, higher grade Zn oxide product (Expatriate Resources Ltd., 2000d). Selenium can be removed from the copper concentrate if necessary by a conventional bioleach process (Expatriate Resources Ltd., 1999b).

Ice

The Ice deposit (Yukon MINFILE, 2001, 105G 118; 61°53'N, 131°21'W; NTS 105G/13) is located about 60 km east of Ross River in the northern part of the Finlayson Lake district in an area of subdued topography with limited outcrop (Fig. 1). The deposit is made up of copper-gold-cobalt mineralization hosted by mafic volcanic rocks of the Campbell Range belt (Eaton, 1996; Eaton and Pigage, 1997; Pigage, 1997; Becker, 1997, 1998) and is the first to be discovered in this belt. The deposit is estimated to contain an indicated mineral resource of 4 561 863 tonnes with a grade of 1.48% copper, including about 3.4 million tonnes of near-surface mineralization (Expatriate Resources Ltd., 1999a). The indicated resource is overlain by a significant amount of surface oxide copper mineralization for which there is insufficient data to estimate a resource (ibid.).

The following description of the Ice deposit is summarized from reports written by Expatriate Resources Ltd. personnel (Pigage, 1997; Becker, 1998) unless otherwise noted.

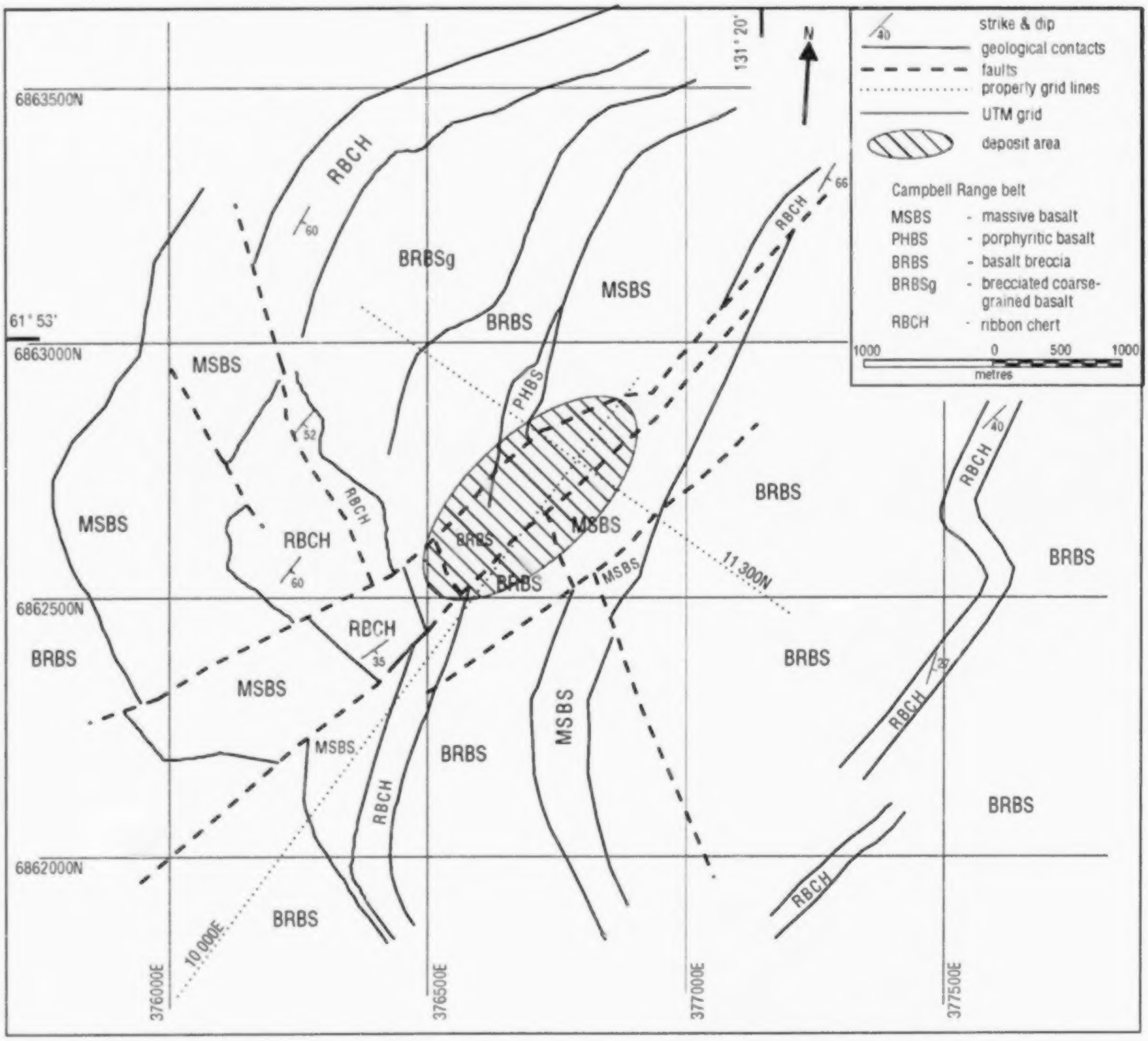
Property geology

The Ice property is underlain primarily by variably strained, sub-greenschist to greenschist facies intercalated basalts, ultramafic and plutonic rocks, and ribbon cherts with associated argillite, sandstone and minor limestone, at the northwest end of the Campbell Range belt (CRB; Fig. 5). This area has not yet been remapped regionally, and therefore, the affiliation of the underlying rocks is uncertain. At the present time, due to their lithological similarity, they are interpreted to be correlative with CRB rocks in the rest of the Finlayson Lake area.

Lithology

Rocks in the immediate vicinity of the Ice deposit consist of massive basalt, porphyritic pillowed basalt and autobrecciated pillowed basalt (Fig. 24) that are lithologically similar to one another and difficult to differentiate. Lithogeochemical data from rocks hosting the Ice deposit show that hanging wall and footwall rocks are tholeiitic basalts with N-MORB composition and ocean floor affinities (Fig. 6 and Appendix VI-2; see also Piercey et al., 1999). The basaltic rocks are interbedded with generally moderately southeast-dipping black, grey, green and red ribbon chert, massive green and red chert, greywacke and carbonaceous mudstone. The rocks types are described below, and a generalized stratigraphic column is shown in Figure 25.

Basal pillow basalt breccia (Fig. 25), the lowermost unit proximal to the Ice deposit, is at least 110 m thick and consists of brecciated aphanitic pillow basalt with pillows up to 1.5 m in diameter. The rock is generally medium green with a pale pink to purple tinge, is nonmagnetic


131°20'
N
6863500N
61°53'
6863000N
6862500N
6862000N
376000E
376500E
377000E
377500E
10,000E
11,300N
RBCH
BRBSg
MSBS
BRBS
PHBS
60
52
66
40
35
30
strike & dip
geological contacts
faults
property grid lines
UTM grid
deposit area
Campbell Range belt
MSBS - massive basalt
PHBS - porphyritic basalt
BRBS - basalt breccia
BRBSg - brecciated coarse-grained basalt
RBCH - ribbon chert
1000
0
500
1000
metres

*UTM zone 9, NAD 27

Figure 24. Bedrock geology map for the Ice deposit (modified from Pigage, 1997).

and locally weakly calcareous. Pillows are readily visible in outcrop and commonly exhibit autobrecciated textures and radial fractures. Locally, red and green chert forms interstitial aggregates between pillows. The brecciated basalt has a dark green chloritic matrix which makes up 5 to 15% of the rock, and subangular to subrounded clasts up to 10 cm in diameter (Fig. 26a). Frequently the clasts have reddish brown rims due to the presence of finely disseminated hematite. Locally, this basalt contains abundant epidote.

Basal mudstone conglomerate (Fig. 25) is a 10- to 15-m-thick, dark grey, carbonaceous mudstone conglomerate. It occurs within the basal pillow basalt breccia about 50 m below the contact with overlying massive basalt. The conglomerate consists of about 60% clasts and 40% matrix. The clasts are unsorted, generally sand-sized, and made up of chert, altered basalt and sandstone; rarely the clasts are up to 5 cm in diameter. The matrix consists of fine-grained mudstone that exhibits a moderate slatey cleavage.

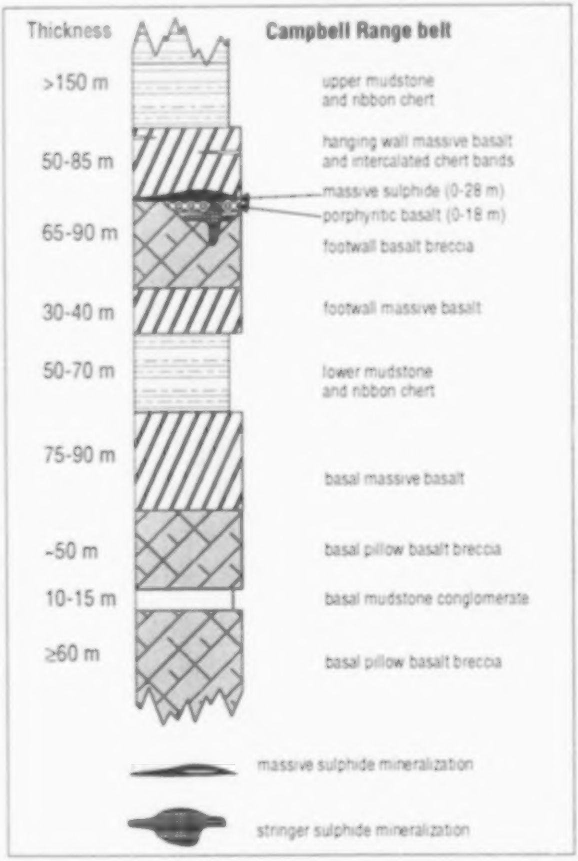

Thickness
Campbell Range belt
>150 m
upper mudstone and ribbon chert
50-85 m
hanging wall massive basalt and intercalated chert bands
massive sulphide (0-28 m)
porphyritic basalt (0-18 m)
65-90 m
footwall basalt breccia
30-40 m
footwall massive basalt
50-70 m
lower mudstone and ribbon chert
75-90 m
basal massive basalt
~50 m
basal pillow basalt breccia
10-15 m
basal mudstone conglomerate
≥60 m
basal pillow basalt breccia
massive sulphide mineralization
stringer sulphide mineralization

***Figure 25.** Simplified stratigraphic column for the Ice deposit (modified from Pigage, 1997).*

Basal massive basalt (Fig. 25), 70 to 90 m thick, conformably overlies basal pillow basalt breccia. The massive basalt is medium green, medium- to coarse-grained and equigranular. It forms resistant, rounded brown outcrops with a distinct salt and pepper appearance due to large grain size. The basalt is partially to completely altered to chlorite and epidote. Individual flows and pillows are not readily apparent.

Lower mudstone and ribbon chert (Fig. 25) conformably overlies the basal massive basalt. It is 50 to 70 m thick and consists of interbedded carbonaceous mudstone and ribbon chert. The dominant rock type is recessive-weathering, soft, noncalcareous, dark grey to sooty black mudstone that locally contains thin interbeds of medium grey, finely laminated calcareous siltstone or dull brown argillaceous siltstone. Locally, the siltstone exhibits graded bedding and small load casts. On weathered surfaces the mudstone is typically coated with patchy brown limonite. Poorly developed slatey cleavage in the mudstone is marked by a micaceous sheen on fresh surfaces. A resistant-weathering, varicoloured ribbon chert that includes grey to black, green and red to maroon varieties is intercalated with the mudstone (Fig. 26b). Sequences of ribbon chert are metres to tens of metres thick and are made up of individual bands 1 to 3 cm thick. The chert beds locally contain closely spaced tension gashes filled by white quartz. In outcrop the lowermost portion of the chert is made up of about 15 m of red and green ribbon chert, however, in drill core these rocks are pale to dark grey.

Footwall massive basalt (Fig. 25), 30 to 40 m thick, conformably overlies the lower mudstone and ribbon chert. The basalt is homogeneous, medium-grained and equigranular. It is compositionally and texturally similar to the basal massive basalt, but is generally less coarsely crystalline (Fig. 26c). In outcrop the footwall massive basalt forms rounded outcrops with a fine, grainy texture. In general this basalt is dark green, except for immediately above the mudstone and chert where it is altered to pale greenish grey dolomite and lesser muscovite (Shearer, 1997).

Footwall basalt breccia (Fig. 25), 65 to 95 m thick, gradationally overlies footwall massive basalt. The transition from massive to brecciated basalt occurs over a few metres to a few tens of metres. The basalt breccia weathers to form nondescript brown outcrops. It consists of 60 to 95% rounded to angular, aphanitic basalt fragments, up to 10 cm across, in a dark green, fine-grained to fragmental, chloritic matrix. The fragments vary from olive to bluish green and have a faint purple or pink tinge when dry. Commonly they have an up to 1-cm-thick concentric outer alteration rim that is pale due to alteration, or maroon due to the presence of finely disseminated hematite. Locally, the matrix contains epidote or quartz or is hematite-rich and dark maroon to bright red in colour. Locally, the footwall basalt breccia contains resistant angular red and green chert clasts that are visible on weathered surfaces. Locally, rounded to tubular pillows, up to 1 m across, are visible in outcrop, as are individual 'beds' about 1 m thick.

Stringer sulphide mineralization is common within the footwall basalt breccia.

Porphyritic basalt (Fig. 25) overlies, and is generally in sharp contact with, footwall basalt breccia but has a limited lateral extent. It is 0 to 18 m thick, aphanitic and dominantly brecciated. The unit is medium green to dark grey-green and noncalcareous. It weathers to form rounded, locally pillowed (up to 1 m), medium brown outcrops that are marked by about 15% green to grey, randomly oriented phenocrysts up to 5 mm across that are visible on weathered surfaces. Phenocrysts consist of equant to tabular, white to bright green plagioclase grains or clusters that are partially to completely saussuritized. Primary plagioclase composition in one specimen is approximately andesine$_{45}$. Breccia fragments are visible only in drill core where clasts up to 10 cm in diameter occur in a dark green chloritic matrix. Locally, the clasts and matrix are dark maroon due to the presence of finely disseminated hematite.

Massive sulphide (Fig. 25) mineralization (see deposit description below and Fig. 26d) occurs between the porphyritic basalt and overlying hanging wall massive basalt. Where porphyritic basalt is absent the massive sulphide horizon lies between footwall basalt breccia and overlying hanging wall massive basalt. Stockwork sulphides are locally developed within the porphyritic basalt.

Hanging wall massive basalt (Fig. 25), 50 to 85 m thick overlies the porphyritic basalt, massive sulphide horizon, or footwall brecciated basalt. It is medium to dark green, equigranular, medium-grained and resembles the underlying massive basalt units. The hanging wall massive basalt weathers to form rounded outcrops with a grainy texture. Epidote occurs locally, replacing primary plagioclase. No pillows have been recognized in this unit.

Massive grey, red and green chert interbeds up to 2 m thick occur locally within the hanging wall massive basalt. The interbeds are laterally discontinuous (seldom over 50 m). Locally, within the basal part of the unit, bright red, siliceous, hematitic mudstone also forms thin interbeds. At contacts with the chert and hematitic mudstone interbeds, the massive basalt commonly displays fine-grained chilled margins.

Upper mudstone and ribbon chert (Fig. 25) is the uppermost stratigraphic unit proximal to the Ice deposit. It consists of at least 150 m of poorly exposed, dark grey to black, carbonaceous mudstone with lesser pale grey, black and pale green ribbon chert interbeds. Overall, this unit is lithologically similar to the lower mudstone and ribbon chert unit. However, in the upper mudstone and chert unit, individual ribbon chert beds are up to 3 cm thick and form intervals up to 5 m thick that are somewhat different from the lower unit. In outcrop the ribbon chert is pale to dark grey, but pale green in drill core. Green chert beds are separated by silvery cream, muscovite-rich phyllitic partings; dark grey chert beds are separated by carbonaceous partings.

The upper mudstone and chert unit contains numerous, recessive-weathering, massive, medium to dark grey, coarse-grained, slightly calcareous greywacke interbeds. Locally, these beds have graded bedding and load casts. One greywacke bed intersected in core was more than 10 m thick and contained internal interbeds of chert and mudstone. At least one lens of brecciated basalt occurs within the mudstone and chert unit, and grades laterally into green ribbon chert.

Metamorphism

The primary mineralogy of the basalts, which consists dominantly of plagioclase laths with interstitial clinopyroxene, has been partially or completely saussuritized. Coexisting mineral assemblages indicate metamorphic grade reached a maximum of upper greenschist facies (Pigage, 1997).

Structure

Near the Ice deposit, bedding generally dips moderately to the southeast, and cleavage dips steeply to the southeast. Cleavage-bedding intersections consistently indicate that the units are structurally upright with an anticlinal hinge to the northwest. The stratigraphy is cut by post-mineralization, northeast-trending, steeply northwest-dipping faults with small (tens of metres to a few hundred metres) probably left lateral strike-slip and normal dip-slip displacement. These faults offset an older fault that has a north-northwesterly strike and near vertical dip (Fig. 24).

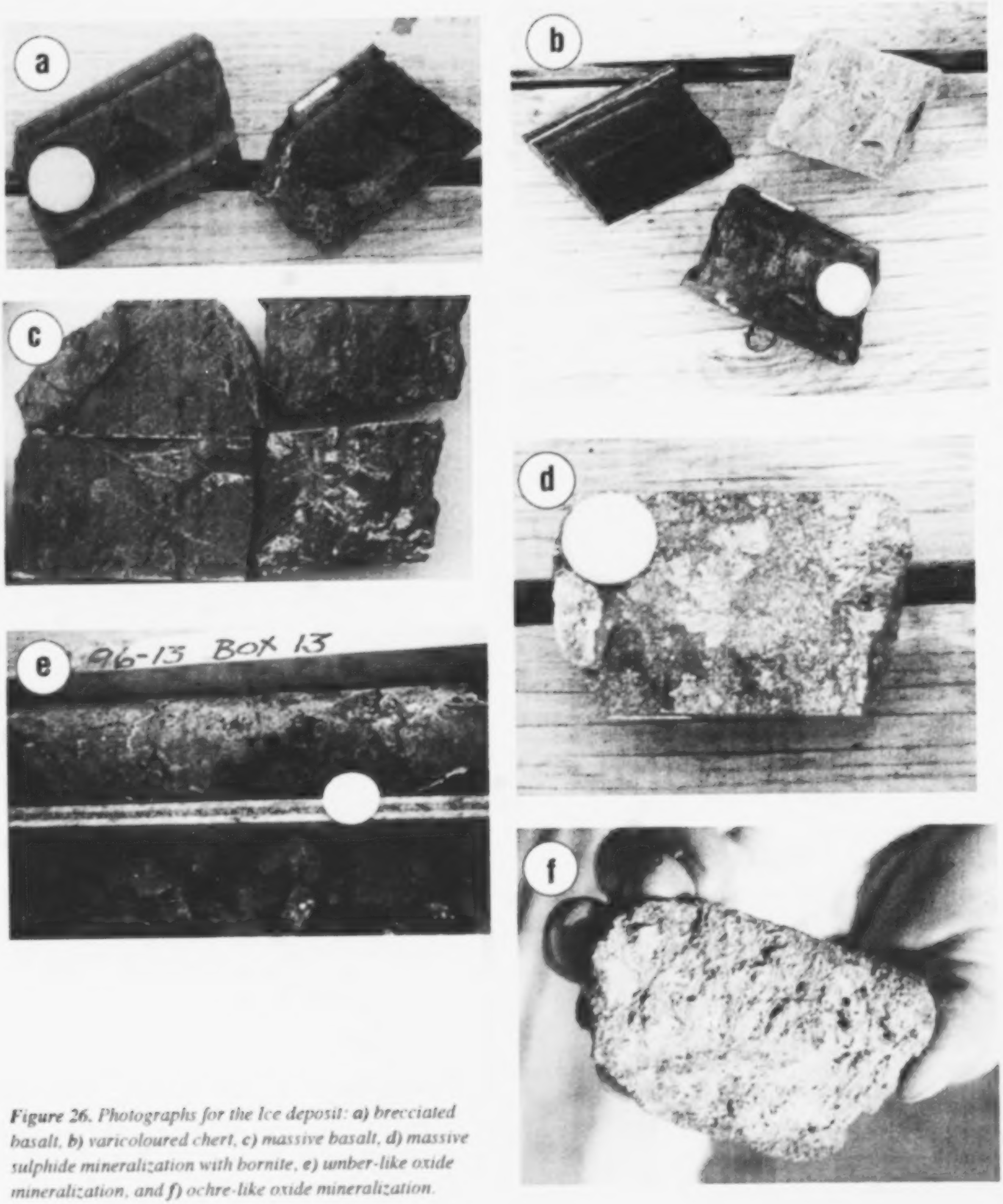


Figure 26. *Photographs for the Ice deposit:* ***a)*** *brecciated basalt,* ***b)*** *varicoloured chert,* ***c)*** *massive basalt,* ***d)*** *massive sulphide mineralization with bornite,* ***e)*** *umber-like oxide mineralization, and* ***f)*** *ochre-like oxide mineralization.*

Footwall massive basalt and porphyritic basalt are not present on the west side of the older fault suggesting that the fault may have been active during volcanism and controlled the deposition of some units (Becker, 1998). The older fault may also have been a major syndepositional control for mineralization as only groundwater-remobilized mineralization has been discovered on its west side. Alternatively, the older fault may have significantly displaced the mineralization.

Deposit description

Primary and secondary mineralization have been found on the Ice property. Primary mineralization occurs as a 0.2- to 28-m-thick massive sulphide horizon that is conformable with stratigraphy, and as zones of stringer sulphides that cross-cut stratigraphy. Secondary mineralization is confined to the zone of near-surface weathering which typically ranges between 5 and 50 m below surface, but extends to almost 80 m along fractures. Secondary mineralization, precipitated from groundwater, includes supergene minerals that have wholly or partially replaced primary sulphide minerals.

Massive sulphide horizon

Massive sulphide mineralization occurs at the contact between hanging wall massive basalt and footwall basalt breccia or locally porphyritic, brecciated basalt (Fig. 25). The massive sulphide horizon is exposed at surface only in road cuts where exposures consist dominantly of friable white to pale orange quartz sand because weathering has leached all sulphides. The upper and lower contacts of the mineralization generally are marked by 5- to 10-cm-thick hematitic chert or mudstone bands. The chert bands typically contain <10% pyrite with trace chalcopyrite and resemble chert clasts found within the sulphide horizon. Along strike and down dip the massive sulphide horizon grades into hematitic chert bands. Hematitic chert and/or mudstone beds occur at several higher stratigraphic levels within the hanging wall massive basalt, indicating that conditions for sulphide deposition may also occur at a number of higher stratigraphic intervals.

The massive sulphide horizon consists of fine- to medium-grained pyrite aggregates disseminated in a gangue of milky white quartz and lesser calcite. Quartz content is typically 30%, but ranges up to 55%. The sulphides are dominated by relatively coarse-grained subhedral to euhedral pyrite intergrown with chalcopyrite, minor sphalerite and locally abundant bornite containing digenite (Fig. 26d). Commonly the sulphides are preserved as distinct breccia. Angular to subrounded pyrite clasts up to 10 cm across in a pyrite-quartz matrix are common. Locally, within the massive sulphide, textures include massive cryptocrystalline to locally banded and colloform sulphide minerals, indicative of low temperature formation (Payne, 1996a). Very fine- to fine-grained massive sulphides are suggestive of recrystallization and remobilization.

Clasts and veins in drill hole IC96-34 (Fig. 27) can be used to distinguish three generations of mineralization. The first phase of sulphides occur in subrounded to subangular clasts 0.1 to 10 cm across composed of fine- to coarse-grained pyrite with minor dark grey cherty quartz. Locally, the clasts form up to 90% of the rock. Rare hematitic chert clasts up to 1 cm across were also noted in the first phase of mineralization. The second phase of mineralization is copper-rich and consists of pyrite, bornite, chalcopyrite and digenite in a gangue of glassy quartz and calcite. This phase forms a coarse-grained matrix around first phase clasts. The third phase of mineralization occurs as veinlets that cut earlier phases. These veinlets are up to 4 mm wide and contain coarse chalcopyrite and bornite with milky quartz and lesser calcite.

The Ice deposit is concentrically zoned (Figs. 27a,b) with a core of thick, high-grade copper mineralization (3.2 to 8.5% Cu over 5.7 to 28.5 m) surrounded by an apron of thinner, lower grade copper mineralization (1.5 to 3% Cu over 1 to 5 m); intersections average 0.5 g/t Au, 15 g/t Ag, 0.3% Zn and 0.08% Co. Although cobalt is present in the mineralization, no cobalt minerals have been identified and it is likely that cobalt is in solid solution with pyrite (Payne, 1996b). Trace element analyses indicate that the massive sulphide mineralization contains low levels of lead (average 49 ppm) and very low amounts of arsenic, antimony, mercury and selenium.

Stringer sulphide mineralization

Stringer sulphide mineralization is developed within the footwall basalt breccia, and to a lesser degree, in the porphyritic basalt. The stringer mineralization occurs stratigraphically below the massive sulphide horizon and is generally separated from it by 10 to 30 m of barren basalt (Figs. 25 and 27c); the two zones are rarely in contact, but are in drill hole ID97-13 (Fig. 27c). The stringer mineralization is up to 46 m thick, has average grades of 0.3 to 1% copper, minor cobalt and low zinc and precious metal values. The stringer mineralization grades from a core of massive quartz-pyrite-chalcopyrite replacement mineralization through quartz-pyrite-chalcopyrite

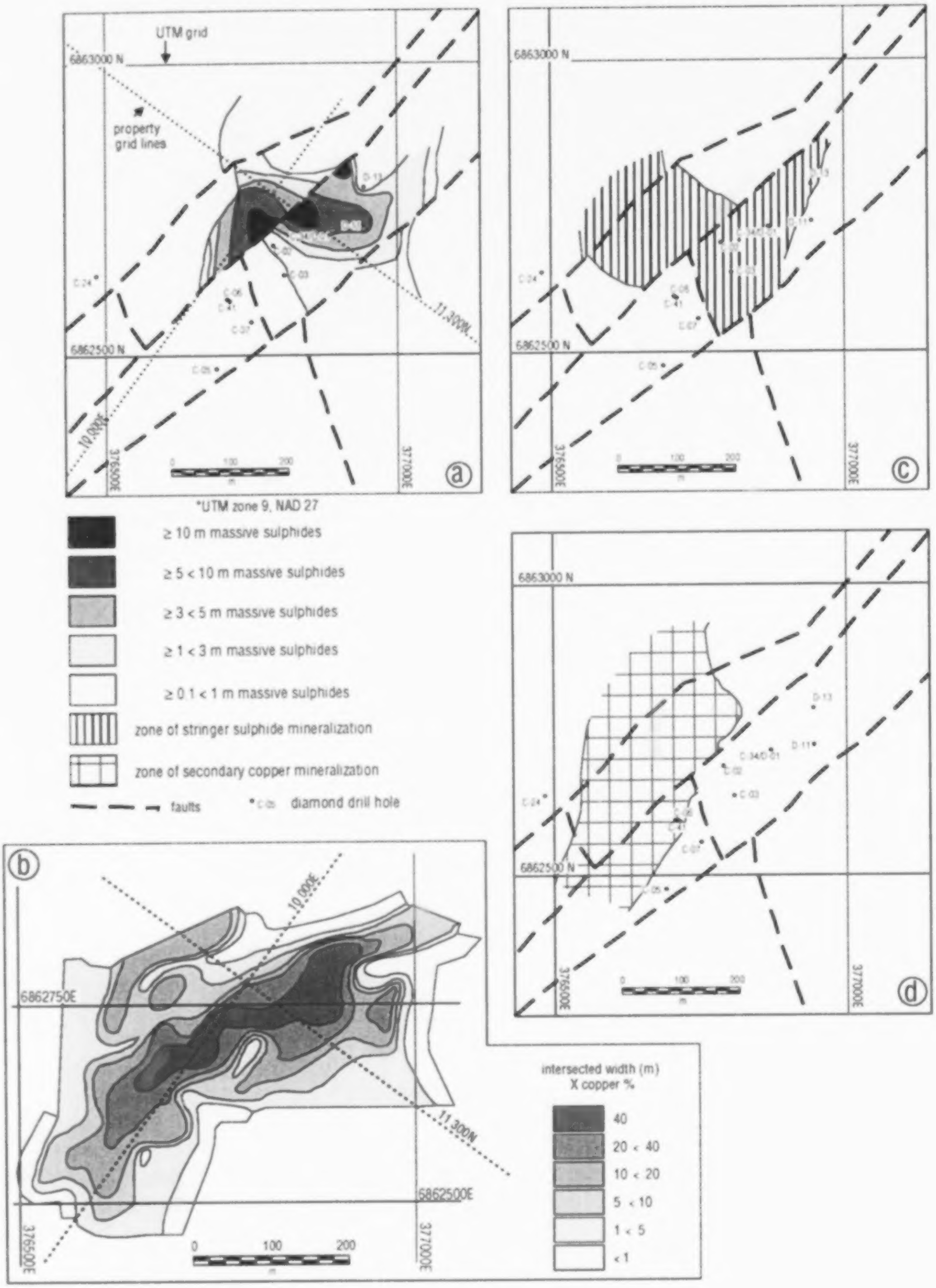

UTM grid
6863000 N
property grid lines
6862500 N
10,000E
11,300N
376500E
377000E
0 100 200
m
ⓐ
ⓒ
ⓓ
ⓑ
*UTM zone 9, NAD 27
≥ 10 m massive sulphides
≥ 5 < 10 m massive sulphides
≥ 3 < 5 m massive sulphides
≥ 1 < 3 m massive sulphides
≥ 0.1 < 1 m massive sulphides
zone of stringer sulphide mineralization
zone of secondary copper mineralization
faults
diamond drill hole
6862750E
6862500E
intersected width (m) X copper %
40
20 < 40
10 < 20
5 < 10
1 < 5
< 1

Figure 27. *Ice deposit:* ***a)*** *massive sulphide isopaths,* ***b)*** *copper zoning,* ***c)*** *area underlain by stringer sulphides, and* ***d)*** *area of secondary copper zone (a, c & d modified from Becker, 1998; b modified from Expatriate Resources Ltd., 1999a).*

stockwork veins to chlorite-pyrite veinlets on the fringes and at depth. Locally, massive sulphide layers up to 10 m thick occur within the stringer zone. Rocks within the stringer zone are intensely chloritized and commonly contain abundant disseminated to semi-massive specular hematite.

Based on cross-cutting relationships, four episodes of mineralization have been identified in the stringer zone. The first episode produced veins, up to 10 cm wide, with dark maroon hematite, quartz and pyrite. The second phase consists of 5- to 10-cm-wide veins containing coarse-grained pyrite and lesser chalcopyrite. The third episode produced 0.5- to 1-cm-wide quartz veins with minor dark yellow fine-grained pyrite and chalcopyrite. The last stage consists of quartz and chlorite in 1- to 1.5-cm-wide veins that cross-cut all earlier phases.

Secondary mineralization

Significant secondary mineralization has been intersected in a 1000 by 500 m zone above and to the west of the massive sulphide horizon (Fig. 27d). Copper appears to be the only metal whose distribution is strongly affected by secondary remobilization. The most common secondary minerals are cuprite, malachite, azurite, black copper oxides, native copper and chalcocite, umber-like hematite (Fig. 26e) and ochre-like limonite (Fig. 26f).

Locally, primary sulphide mineralization has been oxidized *in situ*. Elsewhere oxidation was followed by leaching which removed the copper, leaving behind copper-depleted limonite boxwork. Fracture-filling mineralization ranges from 0.3 to 1.5% copper with low values for all other metals. Locally, chalcocite forms replacement rims on primary sulphide grains. In areas where the secondary mineralization overprints primary mineralization, copper grades average 1.5 to 2.5%, but are locally enriched to 8.2%.

Exploration techniques

The Ice deposit lies in an area with limited outcrop and extensive vegetation cover. The first indications of mineralization in this area were from a single anomalous soil sample and two regional stream sediment samples. The stream sediment samples were weakly anomalous in Cu (63 and 40 ppm), Fe (3.00 and 2.21%) and V (71 and 40 ppm) in samples 105G 873013 and 14, respectively (Hornbrook and Friske, 1988).

The Ice deposit is marked by a 1400-m-long and up to 500-m-wide area of moderately to extremely anomalous copper, with coincident anomalous zinc and cobalt in the vicinity of known mineralization. Peak values returned by soil samples were >10 000 ppm copper, 1450 ppm zinc and 200 ppm cobalt. Geochemical responses for other metals are generally subdued and show little direct correlation with the main indicator metals or areas of surface mineralization.

The collection and interpretation of geochemical data in this area is complicated by thick vegetation and patchy glacial till cover. Locally, erroneous soil geochemical anomalies are created by hydromorphic transport of metals in groundwater and glacial dispersion of mineralization. However, part of the surface area overlying the deposit is marked by a 30-m-diameter vegetation kill zone with malachite-cemented glacial till (Eaton, 1996; Pigage 1996a). Mineralized basalt outcrops with abundant malachite and lesser azurite on fractures are located near the kill zone.

Published regional airborne geophysical surveys for the Finlayson Lake map area (Geological Survey of Canada, 1963) show a westerly trending, broad magnetic high over the Ice deposit, likely reflecting the aerial distribution of meta-basalt and ultramafic rocks in this area of the Campbell Range belt.

SIGNIFICANT MINERAL OCCURRENCES

Following are brief descriptions of significant VMS occurrences in the Finlayson Lake district. The occurrences have been divided into those which are hosted within 1) the Grass Lakes succession, 2) the Campbell Range succession and 3) rocks of unknown affinity.

1) Within the Grass Lakes succession

Pack (Pak)

The Pack (Pak) property (Yukon MINFILE, 2001, 105G 032; 61°20'50"N, 130°36'20"W) is located on the east side of NTS map 105G/7 in an area underlain by units Mk, Mm and Mcp of the Grass Lakes succession (Fig. 4; Murphy and Piercey, 1999b). Mineralization has been found in two zones: Pak and East Cirque (Baknes, 1994, 1995; Gale et al., 1998; Yukon MINFILE, 2001). In the Pak zone mineralization consists of massive pyrrhotite with chalcopyrite and sphalerite-rich bands hosted mainly by felsic metavolcanic rocks in a series of fold noses. A chip specimen from the Pak zone returned 4.97% Cu, 1.08% Pb, 2.71% Zn, 62.0 ppm Ag and 340 ppb Au over

0.8 m (Baknes, 1995; Yukon MINFILE, 2001). The East Cirque zone is located 750 m east of the Pak zone and is made up of rusty-weathering siliceous rocks and magnetite iron formation sandwiched between mafic metavolcanic rocks. A grab specimen from the East Cirque zone returned 100 ppm Cu, 5830 ppm Pb, 1.3% Zn and 4.4 ppm Ag (Baknes, 1994; Yukon MINFILE, 2001).

Blueline

The Blueline property (Yukon MINFILE, 2001, 105G 120; 61°20'50"N, 130°54'10"W) is located on the west side of NTS map 105G/7 in an area underlain by units Dq, Dm and Df of the Grass Lakes succession (Fig. 4; Murphy and Piercey, 1999b). The property is, in part, underlain by felsic metavolcanic rocks and 20-m-thick rusty-weathering, pyritic micaceous quartzite (Wengzynowski, 1998a, 1999a). Soil geochemistry outlined a multi-element anomaly 2 km in diameter over the gossanous quartzite (Eaton, 1997a). A float sample of felsic schist with wispy foliaform and disseminated sphalerite and galena returned 4.22% Pb, 4.92% Zn and 9.0 g/t Ag. Locally, rusty-weathering float containing arsenopyrite returned up to 10.29 g/t Au. An airborne geophysical survey outlined a magnetic anomaly that is coincident with anomalous soil geochemistry and felsic metavolcanic rocks and an electromagnetic (EM) conductor that is parallel to the metavolcanic rocks (Woolham, 1996). An airborne radiometric survey (Geological Survey of Canada, 1998) outlined a potassium high in this area.

Pneumonia (Mony)

The Pneumonia (Mony) property (Yukon MINFILE, 2001, 105G 081; 61°16'57"N, 130°10'52"W) is located in the southeast corner of NTS map 105G/8 in an area underlain by the Kudz Ze Kayah felsic metavolcanic unit (Mk) of the Grass Lakes succession (Fig. 4; Murphy and Piercey, 1999b). Mineralization on the Pneumonia property includes small discontinuous lenses of galena within pyritic felsic metavolcanic rocks, and possible exhalite horizons made up of laminated magnetite ± pyrite-sphalerite-galena and manganiferous quartz-barite (MacRobbie, 1995c, 1996b; Senft, 1997). Grab specimens of float of pyritic quartz-sericite schist with disseminated to banded sphalerite ± chalcopyrite-galena returned up to 2.1% Zn, 0.4% Cu, 0.3% Pb and 17.5 g/t Ag. Several electromagnetic (EM) conductors and numerous magnetic features have been outlined on the Pneumonia property (Jackish, 1995).

Akhurst (Expo)

The Expo property is a large claim block at the southeast end of the Finlayson Lake district underlain, in part, by the Grass Lakes succession (Fig. 4, in pocket; Murphy and Piercey, 1999b). The Expo property includes the Akhurst, Ellen Creek, White Creek and Pop occurrences (Yukon MINFILE, 2001, 105G 082, 61°12'59"N, 130°12'45"W; 105G 135, 61°08'20"N, 130°13'59"W; 105G 136, 61°13'41"N, 130°15'38"W; and 105G 138, 61°12'03"N, 130°16'31"W).

The Akhurst area is underlain by felsic metavolcanic rocks, and carbonaceous phyllite and schist with minor interlayered mafic metavolcanic rocks (MacRobbie, 1995b,d). This area hosts several showings including chloritic felsic metatuff with baritic and manganiferous siliceous exhalite containing sphalerite and minor galena mineralization, massive barite, and hornfelsed/skarned mafic metavolcanic rocks that returned 3.4% Zn, 2.8 g/t Ag and 80 ppb Au (MacRobbie, 1995b,d; Bannister, 1997a; Tulk, 1997). Contour and grid soil sampling in the Akhurst area identified strong lead-copper-silver-zinc anomalies and ground geophysical surveys identified horizontal-loop electromagnetic (HLEM) conductors and magnetic anomalies (Jackish, 1995).

The Ellen Creek area is underlain, in part, by rusty-weathering felsic metatuff interlayered with pyritic felsic metaflows (Bannister, 1997a; Tulk, 1997; MacRobbie and Senft, 1999). Locally, the metatuff contains zinc and copper mineralization, and samples returned up to 1.5% Zn and 0.1% Cu. Soil sampling outlined an area of moderate to strongly anomalous Pb (>50, maximum 1287 ppm), Zn (>100, maximum 1091 ppm) and Cu (>50, maximum 290 ppm).

The White Creek area is underlain, in part, by felsic metatuffs and flows. Mineralization consists of at least three bands, each up to 1 m thick, of massive pyritic barite locally with pyrrhotite-sphalerite ± magnetite. The mineralization is hosted by a sequence of siliceous, barite-carbonate-altered felsic metavolvanic flow rocks or tuffs and argillite about 10 m thick (MacRobbie, 1995b,d; Bannister, 1997a; Tulk, 1997). Grab samples from the upper and lower mineralized bands returned up to 0.9% Zn, 8.2 g/t Ag and 43% Ba. Soil sampling returned weak to moderately anomalous values for Zn (maximum 582 ppm), Cu (maximum 320 ppm) and Ag (maximum 6.9 ppm).

The Pop area is underlain by poorly exposed felsic metavolcanic and metasedimentary rocks and minor mafic metavolcanic rocks. This area contains the Berdahl showing, a small hydrozincite, malachite, azurite-stained outcrop of brecciated, rusty felsic and intermediate to mafic metavolcanic rocks with fracture-filling calcite-quartz-sphalerite-galena-chalcopyrite mineralization. A grab sample of the mineralization returned 13 160 ppm Zn, 10 260 ppm Pb, 1675 ppm Cu and 37 g/t Ag (MacRobbie, 1995b). The Berdahl showing is marked by coincidental geophysical electromagnetic (EM) and magnetic anomalies (Jackish, 1995). Other mineralization in this area includes disseminated sphalerite and chalcopyrite in chlorite-sericite-quartz-calcite veinlets in felsic metaflows, and pyrite-pyrrhotite ± sphalerite-chalcopyrite as foliation-parallel disseminations and fracture fillings within chloritic metavolcanic rocks (Bannister, 1997a; Tulk, 1997).

Ant (Hat Trick)

The Ant (Hat Trick) property (Yukon MINFILE, 2001, 105G 098; 61°31'16"N, 130°46'26"W) is located on the west side of Fire Lake (NTS 105G/2) in an area likely underlain by rocks of the Grass Lakes succession (Fig. 4; Murphy and Piercey, 1999b). The property is, in part, underlain by a 10- to 30-m-thick recessive weathering pyritic quartz-muscovite/sericite schist horizon that extends along strike for approximately 2000 m (Eaton, 1997b; Wengzynowski, 1996b, 1998b). The schist horizon contains medium- to coarse-grained, semi-massive sphalerite-galena-chalcopyrite-pyrite mineralization. Float samples of the mineralization returned up to 17.6% Zn, 5.68% Pb, 4.00% Cu, 302 g/t Ag and 1.5 g/t Au. Drilling of the quartz-muscovite/sericite schist horizon intersected 0.81 m of disseminated sphalerite-chalcopyrite-galena mineralization that returned 1.56% Zn, 20.2 g/t Ag, 3460 ppm Cu and 2460 ppm Pb. A horizontal-loop electromagnetic (HLEM) conductor is coincident with the recessive horizon (Woolham, 1996).

Other mineralization on the Hat Trick property includes up to 1-m-thick zones of disseminated pyrite in fractured chlorite-biotite phyllite, an up to 3-m-thick zone of disseminated pyrite-pyrrhotite-chalcopyrite in amphibolite, and a 2-m-thick band of malachite-stained chlorite-biotite phyllite in calcareous quartzite (Wengzynowski, 1998b).

Goal-Net

The Goal-Net property is a large claim block, underlain mainly by the Grass Lakes succession (Murphy and Piercey, 1999b), that includes the Blade, Goal, Goon, Net, NHL and Overtime claims (Fig. 4, NTS map sheets 105G/7 and 8; the centre of the property is located at 61°20'N, 131°32'W). The Goal-Net property contains at least twelve mineral targets, the most significant of which is located about 12 km southeast of Kudz Ze Kayah and 6 km from GP4F in a thick section of Kudz Ze Kayah-equivalent stratigraphy (Wengzynowski, 1999b). This area is underlain by a 400- to 700-m-thick package of quartzite and interlayered felsic and mafic metavolcanic rocks sandwiched between underlying augen orthogneiss and/or Cretaceous granite and an overlying ultramafic unit. The metavolcanic rocks include a laterally extensive magnetite-rhodochrosite exhalative sequence overlying sulphide-bearing exhalite horizons, that has been traced intermittently for about 1600 m along strike. Surface samples returned up to 45.2 g/t Ag, 1.01% Cu, 1.45% Pb, 8.31% Zn and 65 ppb Au (Wengzynowski, 1999b). Drilling intersected sulphide mineralization in quartz-porphyritic metarhyolite that is similar to the felsic metavolcanic strata that hosts the GP4F deposit (Expatriate Resources Ltd., 2001). Semi-massive sulphide mineralization, 0.73 m thick, returned values of 3.0% Zn, 1.85% Pb, 0.14% Cu, 63 g/t Ag and 0.2 g/t Au (Expatriate Resources Ltd., 2000f). Soil geochemistry has outlined two areas with anomalous Pb (>50 ppm) values (Expatriate Resources Ltd., 2001).

Red Line

The Red Line property (Yukon MINFILE, 2001, 105G 124; 61°25'30"N, 130°21'53"W) is located west of Wolverine Lake (NTS 105G/8) in an area underlain by the Grass Lakes succession that has been intruded by massive and augen gneiss of the Mississippian Grass Lakes plutonic suite (Fig. 4; Murphy and Piercey, 1999b). Soil sampling defined a 200 x 500 m area of strongly anomalous copper and zinc values that includes a linear recessive zone with limonitic boxwork-textured float (Wengzynowski, 1996c). A 700-m-long magnetic high is roughly coincident with an east-trending MaxMin conductor centred over the area of maximum geochemical response (Holroyd, 1997). Drilling intersected disseminated to wispy stringer sulphide mineralization associated with quartz veins; samples returned up to 5.60% Cu, 0.08% Pb, 0.50% Zn and 76.6 g/t Ag over 0.11 m (Pigage, 1996b). This mineralization is correlated with the GP4F deposit horizon (Expatriate Resources Ltd., 2001).

Cobb

The Cobb property (Yukon MINFILE, 2001, 105G 127; 61°31'16"N, 130°46'26"W) is located east of Big Campbell Creek (NTS 105G/7) in an area underlain by the Kudz Ze Kayah felsic metavolcanic unit of the Grass Lakes succession (Fig. 4; Murphy and Piercey, 1999b). The property is, in part, underlain by thick felsic crystal metatuff interlayered with felsic metaflows and lesser metasedimentary rocks (Bannister, 1997b). Rocks underlying the Cobb property likely occur just below or at the same stratigraphic level as Kudz Ze Kayah (ibid.). Airborne geophysical surveys delineated two areas with coincident magnetic and electromagnetic (EM) anomalies (Holroyd, 1996). Sphalerite-galena-pyrite mineralization occurs as fine to blotchy disseminated patches parallel to foliation, as fracture fillings in metasedimentary rocks and as thin galena-chalcopyrite laminae in felsic crystal metatuff (Bannister, 1997b). Soil sampling outlined coincident anomalies of Pb-Zn-Cu (Pb >75, maximum 1003 ppm; Zn >400, maximum 5638 ppm; Cu >50, maximum 375 ppm) over a distance of 500 m.

League

The League property (Yukon MINFILE, 2001, 105G 130; 61°31'16"N, 130°46'26"W) is located about 11 km northwest of the Kudz Ze Kayah (ABM) deposit in an area underlain by Nisling and Nasina assemblages (Fig. 5; Gordey and Makepeace, 1999). Most of the League property is heavily vegetated, and blanketed with glacial till. The property is in part underlain by intermediate to felsic metavolcanic rocks that overlie a thick carbonaceous calcareous phyllite unit (Eaton, 1997c; Pigage in Eaton, 1997c; Wengzynowski, 1998c). This sequence is intruded by weakly foliated quartz-feldspar metaporphyry (*ca.* 356 Ma old - Mortensen, written communication, 1997) similar in age to that at Kudz Ze Kayah (Piercey et al., 2001). Geochemical soil anomalies are associated with the above sequence where muscovite-quartz phyllite occurs structurally beneath massive, aphanitic grey metarhyolite and above massive chloritic metabasalt (Pigage in Eaton, 1997c). Drill core samples of the muscovite-quartz phyllite and aphanitic metarhyolite contain elevated levels of lead and zinc, and at least one drill hole contains thin sulphide-quartz stringers with pyrite and associated sphalerite and galena. Results include 0.01% Cu, 0.87% Pb and 0.1% Zn over 1.29 m, and 0.01% Cu, 0.07% Pb and 0.42% Zn over 1.48 m.

Stream sediment samples from a creek draining the League property returned strongly anomalous results of up to 212 ppm Cu, 336 ppm Pb and 1700 ppm Zn and moderately anomalous (up to 5 ppm) Mo values (Pigage in Eaton, 1997c). Results from soil samples outlined a 1500 x 600 m area with coincident, weak to strongly anomalous values for Pb, Zn, Ag, Mo, Sb, As, Mn and Au. This anomalous zone contains a 600 x 200 m core area which contains some of the highest geochemical values obtained in the Finlayson Lake area. Airborne and ground geophysical surveys over the League property outlined numerous electromagnetic (EM) conductors.

Nad

The Nad property (Yukon MINFILE, 2001, 105G 140; 61°20'25"N, 130°07'45"W) is located on the east side of NTS map 105G/8 in an area underlain by the Grass Lakes succession and the Wolverine Lake succession (Fig. 4; Murphy and Piercey, 1999b). Drilling on the property intersected a strongly foliated, isoclinally folded, sequence of layered felsic metavolcanic and metasedimentary rocks that contains a 0.2-m-thick band of massive pyrrhotite-pyrite-marcasite-chalcopyrite-sphalerite-magnetite that returned 2.6% Zn, 0.6% Cu, 0.3% Pb and 23.0 g/t Ag (MacRobbie, 1995e,1996b; Senft, 1997). Soil samples returned coincidentally anomalous lead and zinc values from an area that overlies felsic metavolcanic rocks. Ground horizontal-loop electromagnetic (HLEM) and magnetic surveys outlined a weak narrow conductor and numerous magnetic features (Senft, 1997).

2) Within the Campbell Range succession

Money (Julia)

The Money (Julia) occurrence (Yukon MINFILE, 2001, 105H 078; 61°24'57"N, 129°58'44"W) is located about 5 km west of the Wolverine deposit on NTS map 105H/5 in an area underlain by rocks of the Campbell Range succession (Fig. 4; Murphy and Piercey, 1999b). Mineralization consists primarily of copper sulphides with lesser zinc, gold and silver. The mineralization is hosted within a sequence of mafic flows and breccia and is associated with maroon and oxidized fine-grained metasedimentary rocks (Baknes, 1997a). Lithogeochemical analysis of two mafic volcanic samples (Appendix VI-2: specimens JH97-135b & 141) shows that they are basalts with an E-MORB signature (part of CRB1 on Figs. 6f, g, h; Piercey et al., 1999).

Geology

The property is underlain by a sequence of mafic metavolcanic rocks intercalated with fine-grained metasedimentary rocks. This sequence is made up of, from bottom to top: 1) a basal unit of monotonous dark green to locally maroon pillowed basalt and basaltic tuff/breccia (Fig. 28a), 2) quartz-sericite-pyrite-altered pillowed basalt and basalt tuff (not always present), locally with weak copper mineralization, 3) massive banded and siliceous pyritic sulphides, 4) maroon shale, 5) pale grey-green and pink tuffaceous and fragmental cherty rock, 6) maroon cherts and mudstones (Fig. 28b), 7) pillow breccia with a maroon mudstone matrix, and 8) an upper unit of dark green massive pillowed basalt (Baknes, 1997a,b).

The metasedimentary units generally strike northwest and dip moderately to the northeast. In general, foliation is parallel to stratigraphy. Deformation is expressed as moderately developed heterogeneous schistosity along pillow selvages and strongly developed schistosity within stockwork zones (Baknes, 1997b). Local strike-slip faults trending parallel to stratigraphy were noted on surface, and are seen as electromagnetic (EM) conductors in geophysical surveys.

Mineralization

Mineralization on the property consists of 1) massive, weakly banded conformable pyrite, and 2) discordant quartz-pyrite-chlorite ± sericite stockwork (Baknes, 1997b). The massive sulphide mineralization forms a tabular layer with a down-dip length of at least 130 m, a strike length greater than 50 m and an average thickness of 1.0 m (Baknes, 1997a,b). The best drill results, from the 1996 drill program, were 1.75% Cu, 21 ppm Ag and 407 ppb Au over 1.0 m (Baknes, 1997b).

Stockwork mineralization occurs on surface and at depth in zones up to 20 m thick that consist of variably silicified metavolcanic and metasedimentary rocks with lesser chlorite ± sericite alteration, and disseminated and stringer-controlled pyrite ± chalcopyrite ± pyrrhotite (Baknes, 1997b). In one drill hole a 10-m-thick bleached, crackle breccia/stockwork zone, occurring 33 m below the massive sulphide mineralization, returned values of 0.4% Cu, 0.2% Zn and 4.6 g/t Ag over 0.6 m (Wilson and Holbek, 1998). Stockwork zones are, at least locally, anomalous in cobalt and relatively low in gold compared to the massive sulphide mineralization.

Exploration techniques

Massive sulphide mineralization is exposed in two drainages. In one of these (informally named Welcome North creek), a 2-m-thick massive pyrite layer with a siliceous matrix, is exposed in a trench and as float boulders (Fig. 28c). Chip samples returned results of 0.17% Cu and 35 g/t Ag (Kallock, 1995). In the other (informally named Boulder creek) there are large float boulders of massive pyritic sulphides; samples returned results of 1.1% Cu, 31.9 g/t Ag and 0.22 g/t Au. Stockwork zones occur on surface in several areas.

Locally, rocks within creeks draining the property are coated with iron oxide deposits (Fig. 28d). Stream sediment samples collected from creeks draining the property were all highly anomalous in copper and zinc and showed a progressive decrease in values downstream from the showings. Soil geochemical surveys identified areas with anomalous copper and zinc values in several drainages. In recent surveys Cu values >90 ppm and Zn values >100 ppm were considered anomalous (Baknes, 1997b). The results of a reconnaissance soil survey indicate that the sedimentary units show a subtle anomalous response in zinc and copper, and gossanous stockwork zones have a very strong anomalous copper response (ibid.).

Geophysical surveys identified several electromagnetic (EM) conductors. These are variably interpreted as fault related anomalies, formational anomalies related to conductive metasedimentary rocks and possibly massive sulphide mineralization, and discordant anomalies associated with alteration zones.

3) Within rocks of unknown affinity

Hoo (Argus)

The Hoo (Argus) property (Yukon MINFILE, 2001, 105G 013; 61°33'09"N, 130°32'57"W) is located on the west side of the Finlayson Lake district (NTS 105G/12) in an area underlain by Nasina Assemblage rocks (Fig. 5; Gordey and Makepeace, 1999) and may be a sedimentary-exhalative- (SEDEX) or VMS-style deposit. The property is in part underlain by thick (>100 m) sequences of carbonaceous and non-carbonaceous phyllite, chloritic phyllite, quartzite, pyritic limestone and minor quartz-biotite-sericite schist (Baknes, 1996). Soil sampling outlined five coincident lead and zinc anomalies within a 3658- x 914-m area (Kallock, 1996; Baknes, 1996; Hulstein, 1994). Trenching and drilling indicates that the mineralization is confined to clastic horizons associated with limestone lenses. The mineralization consists of sphalerite-galena-pyrite as intergrowths, semi-conformable replacement masses, stringers within quartz and marble, and foliation-parallel massive to disseminated bands. Significant results include 2.67% Zn, 0.75% Pb and 11.0 g/t Ag over 15 m, and 3.26% Zn, 0.86% Pb and 18.7 g/t Ag over 10.1 m (Baknes, 1996).

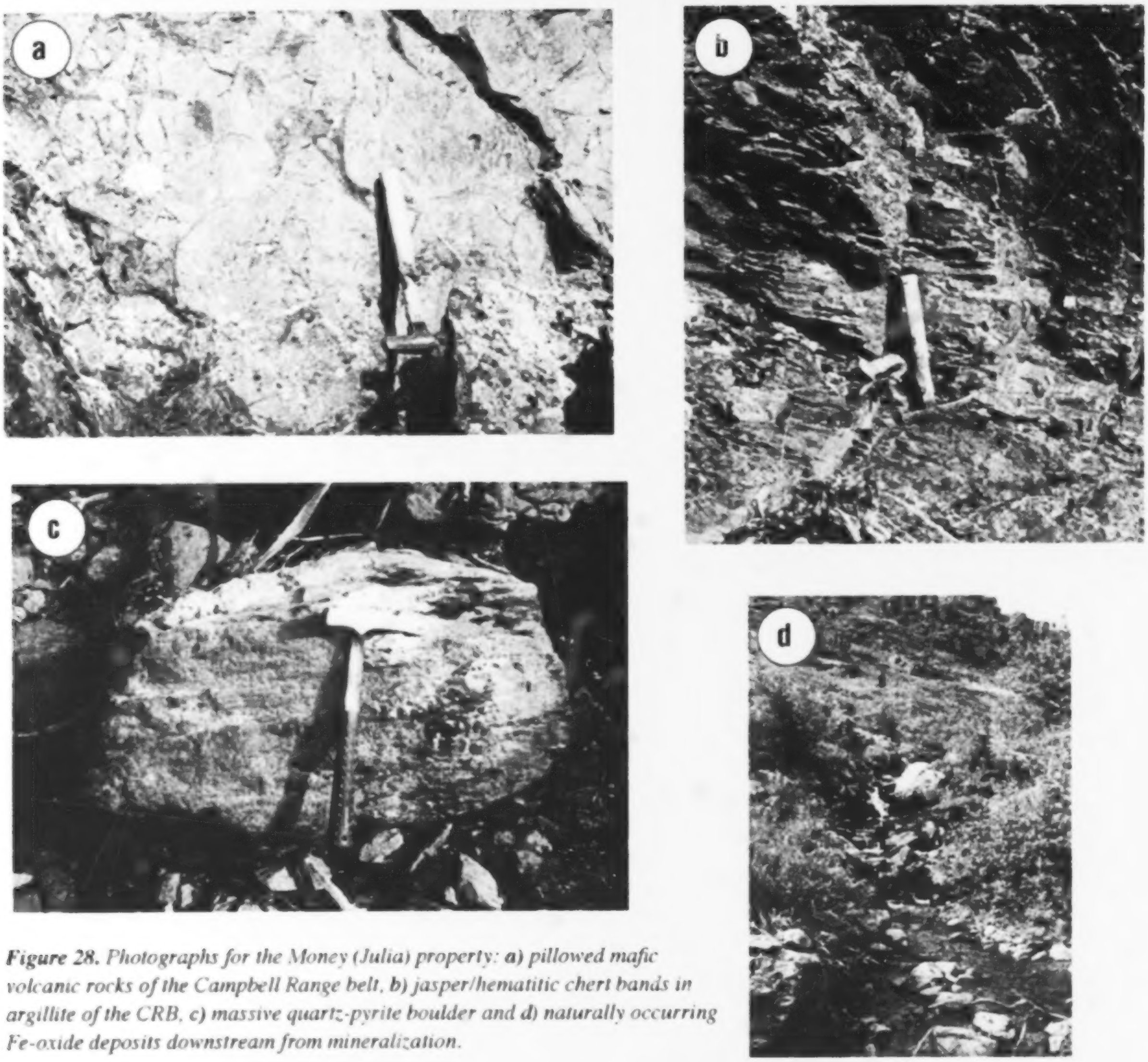


Figure 28. *Photographs for the Money (Julia) property:* ***a)*** *pillowed mafic volcanic rocks of the Campbell Range belt,* ***b)*** *jasper/hematitic chert bands in argillite of the CRB,* ***c)*** *massive quartz-pyrite boulder and* ***d)*** *naturally occurring Fe-oxide deposits downstream from mineralization.*

El (Tin)

The EL (Tin) property (Yukon MINFILE, 2001, 105G 016; 61°28'26"N, 131°18'42"W) is located on the west side of the Finlayson Lake district (NTS 105G/12) in an area underlain by Nasina Assemblage rocks (Fig. 5; Gordey and Makepeace, 1999). The property is, in part, underlain by felsic metavolcanic rocks including aphyric metaflows and feldspar augen schist similar to those in the Kudz Ze Kayah area (MacRobbie, 1995a, 1996a). Sphalerite ± galena-pyrite occur as disseminations and in veins in iron-carbonate-altered felsic metavolcanic rocks.

Eldorado

The Eldorado property (Yukon MINFILE, 2001, 105G 048; 61°42'55"N, 131°42'45"W) is located on the west side of the Finlayson Lake district (NTS 105G/12) in an area underlain by Pelly Gneiss (Fig. 5; Gordey and Makepeace, 1999). The property is in part underlain by carbonaceous metasedimentary rocks locally interlayered with intermediate to felsic metatuffs (Keyser, 1996). Drilling intersected 0.3 m of massive arsenopyrite-pyrite-sphalerite mineralization at the contact between sericitic metavolcaniclastic rocks and overlying graphitic metasedimentary rocks which returned up to 3.6 g/t Au over 0.3 m.

Py (Ty)

The Py (Ty) property (Yukon MINFILE, 2001, 105G 083; 61°09'07"N, 130°08'17"W) is located at the southeast end of the Finlayson Lake district (NTS 105G/1) in an area underlain by Nasina Assemblage rocks (Fig. 5; Gordey and Makepeace, 1999). Outcrops on the property are made up, in part, of a sequence of quartzite, quartz-sericite schist and quartz-K-feldspar augen schist. The quartz-sericite schist hosts pyrite-rich layers up to 12 m thick that contain up to 15% pyrite with minor chalcopyrite and sphalerite and rare galena (Schmidt, 1995; Harman, 1996; Terry et al., 1996; Terry and Gale, 1998, Terry, 1998). Samples returned up to 0.03% Cu, 0.20% Pb and 0.98% Zn. Drilling to test the quartz-sericite schist intersected about 40 to 60 m of grey aphyric to fragmental metarhyolite and green to grey rhyolitic to dacitic metatuff and crystal metatuff underlain by K-feldspar ± quartz augen and quartz-augen schist (Terry et al., 1996, 1997b). Mineralization within the drill holes consists of up to several percent disseminated to massive pyrite, with lesser pyrrhotite and trace chalcopyrite and sphalerite. Massive 0.2-m-thick pyrite returned 90 ppb Au, 1.4 ppm Ag and 1170 ppm Cu. A 2.6-m-thick massive to fragmental metarhyolite with 5-10% disseminated pyrite and <1% sphalerite returned 2.9 ppm Ag, 571 ppm Pb and 3165 ppm Zn. Airborne geophysical surveys returned a flat magnetic response but identified several discrete electromagnetic (EM) conductors (Terry et al., 1996; Terry and Gale, 1998).

Elsewhere on the property quartz-sericite schist and interlayered argillite hosts a 4-m-thick barite unit. Samples of the barite returned >10 000 ppm Ba and low concentrations of metals (Terry, 1998).

DAWSON AREA, YUKON

Restoration of the postulated 425 km of right-lateral, post mid-Cretaceous movement (Roddick, 1967; Tempelman-Kluit, 1976; Mortensen, 1983; Gabrielse, 1991) on the Tintina Fault brings the massive sulphide-rich Finlayson Lake area of the Yukon-Tanana Terrane (YTT) adjacent to the main body of the YTT west of Dawson City (Figs. 1, 29). Mortensen (1990) states that there are close similarities in lithology, structure and U-Pb zircon ages between metamorphic bedrock of the YTT in the Klondike District and in the Finlayson Lake district of southeastern Yukon. The geological similarities between these areas, the proximity of the two areas after restoration of fault movement on the Tintina Fault, and the presence of several sulphide showings in the Dawson area suggests that significant VMS potential extends into YTT rocks in west-central Yukon.

GEOLOGY

The Yukon-Tanana Terrane (YTT) in the Dawson area is made up largely of two packages of rocks (Mortensen, 1992a; Johnston and Mortensen, 1994; see also Mortensen, 1996 for information on the northern Stewart River map area):

1) The Nasina Assemblage or Nisutlin sub-terrane - a Late Devonian to middle Mississippian package of carbonaceous quartzite, quartz-mica schist, marble, mafic and felsic metavolcanic rocks, and lesser amounts of metaplutonic rocks that is interpreted as a continental arc sequence.
2) A package of felsic metavolcanic, metaplutonic and quartzose metasedimentary rocks of primarily middle-Permian age that includes the Klondike Schist, and is interpreted as a continental arc sequence or an anorogenic magmatic suite.

The rock packages are, at least in part, calc-alkaline in composition (Mortensen, 1990; Metcalf, 1981). Mortensen (1992a) considers the abundant Devono-Mississippian metavolcanic rocks in the Finlayson Lake area to be lateral facies equivalents to the Nasina Assemblage in the Dawson area.

Base metal mineralization is known to occur within the Nasina Assemblage and the Klondike Schist in the Dawson area as described below (Figs. 29, 30). The Matson Creek, Baldy (Bal), Pub, Bronson, and Floc prospects are hosted by rocks mapped as Klondike Schist (Gordey and Makepeace, 1999). The Clip, Mickey, Mort, Holly, Pup, Fan, Coal, Swde and Bruin prospects occur in rocks mapped as the Nasina Assemblage. The Top, Fresno and River prospects are hosted by Paleozoic rocks of unknown affinity.

Overall, the strata and mineralization on the various properties are similar and they have been explored as potential hosts for lead-zinc-barium volcanic-hosted or SEDEX massive sulphide mineralization (Carne, 1991b, d).

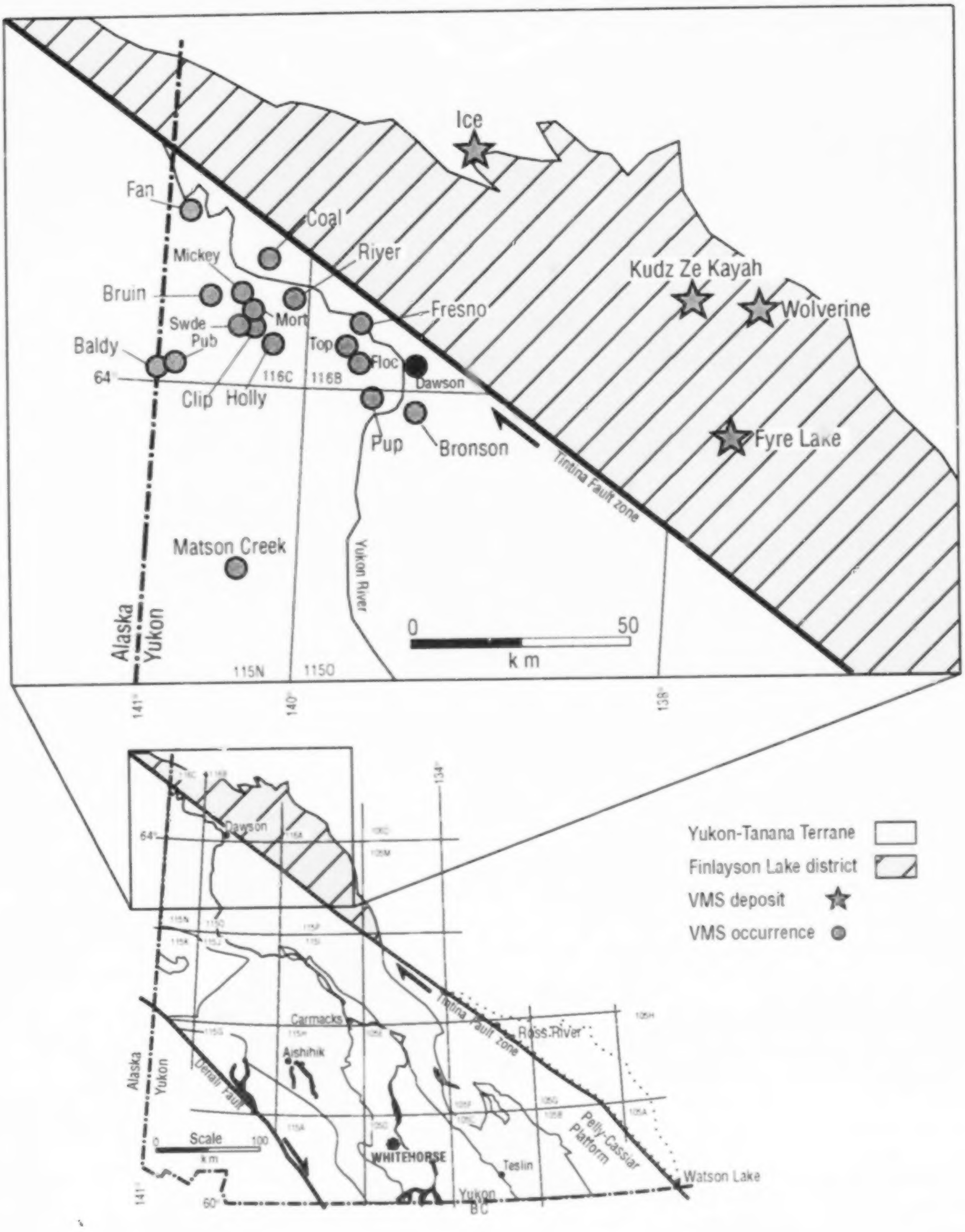

Ice
Fan
Coal
River
Mickey
Bruin
Mort
Swde
Pub
Baldy
Fresno
Top
Floc
Dawson
64°
116C
116B
Clip
Holly
Pup
Bronson
Kudz Ze Kayah
Wolverine
Fyre Lake
Tintina Fault zone
Matson Creek
Yukon River
0
50
km
Alaska
Yukon
115N
115O
141°
140°
138°
134°
Carmacks
Aishihik
Ross River
Denali Fault
Scale
100
WHITEHORSE
Teslin
Pelly-Cassiar Platform
Watson Lake
Yukon
BC
60°
Yukon-Tanana Terrane
Finlayson Lake district
VMS deposit
VMS occurrence

Figure 29. Location of the Finlayson Lake district after restoration of strike-slip movement on the Tintina Fault. Inset map shows the location of VMS occurrences in the Dawson area.

MAIN MINERAL OCCURRENCES

Base metal occurrences in Late Devonian to mid-Mississippian Nasina Assemblage

Clip, Mickey, Mort and Holly

The Clip, Mickey, Mort and Holly occurrences (Yukon MINFILE, 2001, 116C 115, 64°13'52"N, 140°23'45"W, NTS 116C/1; 116C 116, 64°19'43"N, 140°29'03"W, NTS 116C/8; 116C 168, 64°17'00"N, 140°25'00"W, NTS 116C/8; and 116C 124, 64°11'N, 140°17'W, NTS 116C/1, respectively; Fig. 29) are hosted by intercalated metasedimentary and metavolcanic rocks of the Devono-Mississippian Nasina Assemblage (Fig. 30; Johnston and Mortensen, 1994). In general, the strata underlying the properties, though deformed by small-scale isoclinal folds, form a homoclinal sequence that strikes north-northwest and dips gently westward (Carne, 1991a).

Clip prospect (Fig. 29) mineralization is made up of bands and stringers of galena in quartzite and thin, stratiform bands of sphalerite, barite and pyrite in micaceous quartzite interlayered with carbonaceous quartzite (Olfert, 1979; Carne, 1991c). Grab samples of this mineralization returned values of up to 9.2% Zn and up to 11.4% Ba. A 500- to 600-m-long by up to 150-m-wide zinc-in-soil anomaly has been defined on the property along with coincident, but more localized, lead anomalies (Olfert, 1979; Carne, 1991c).

The **Mickey** (Mic) property (Fig. 29) and surrounding area are underlain primarily by medium to dark grey, fine-grained carbonaceous, quartz-muscovite ± chlorite, biotite schists and muscovite-bearing quartzite (Schmidt, 1996d). Rusty-weathering, pyritic quartz-muscovite-chlorite schist on the west side of the property has been interpreted as a possible felsic metavolcanic unit within a metasedimentary sequence (Carne, 1991a). Oxidized sphalerite, bands of galena, and disseminated pyrite occur in vuggy gossanous rocks (Carne, 1991a).

Large coincident lead- and zinc-in-soil anomalies occur on the east side of the property and low level zinc, copper and isolated lead anomalies accompany barium anomalies on the west side of the property (Schmidt, 1996d). Schmidt (1996d) reports that there is a strong correlation between lead, zinc, copper and barium analyses and that copper and barium appear to be useful pathfinder elements on the Mickey property. The source of the geochemical anomaly is believed to be a 3.5-km-long, northerly-trending zone of barite-lead-zinc mineralization, that occurs upslope from the soil geochemical anomalies (Carne, 1991a). Carne (1991a) suggests that geochemical response immediately over the proposed source mineralization is masked by deep, frozen, residual overburden and is complicated by oxidation and leaching. Geophysical surveys detected several electromagnetic (EM) conductors which may be related to mineralization (Olfert, 1979; Carne, 1991a).

The **Mort** occurrence (Fig. 29) is marked by several thin concordant bands of galena and oxidized sphalerite in a 1- to 2-m-thick layer of quartz-muscovite phyllite exposed in a roadcut on the Clinton Creek road (Carne, 1991b). Anomalous values of lead and zinc in soil correlate with the projected trace of stratiform mineralization (ibid.).

The **Holly** occurrence (Fig. 29) is underlain by carbonaceous quartzite, and phyllite that contains a number of thin, mineralized, locally baritic horizons (Olfert, 1980). Mineralization generally consists of thin bands (0.5-2 cm thick) of sphalerite in buff, micaceous quartzite. Locally, disseminated galena and pyrite ± pyrrhotite are associated with the sphalerite. Trenching exposed a section of buff quartzites 7 to 8 m thick with disseminations and thin bands of sphalerite and trace galena (ibid.). A large area, 1.5 to 1.7 km long and 0.5 to 0.7 km wide, returned anomalous values of lead and zinc in soils. Common values within this anomalous area are 150-350 ppm Zn (highest values are >700 ppm) and 50-150 ppm Pb (highest value was 870 ppm; ibid.). Creeks draining this area contain elevated levels of zinc (117-223 ppm) and lead (27-46 ppm; ibid.).

Pup

The Pup (Fig. 29; Yukon MINFILE, 2001, 116B 072; 64°02'N, 139°40'W; NTS 116B/4) property is underlain by Nasina Assemblage and Klondike Schist, however, lead isotope analysis of a lead-bearing soil sample from the Pup property indicates a Mississippian age for the mineralized source (Pride, 1996c) based on the shale model of Godwin and Sinclair (1982). Nasina Assemblage rocks are made up of graphitic and non-graphitic quartzite, and quartz-

Figure 30. *(next page) Bedrock geology and regional silt sample survey results for the Dawson area. Also shown are the location of base metal mineral occurrences. Bedrock geology is from Gordey and Makepeace (1999). Regional silt sample survey results are from Geological Survey of Canada (1978), Hornbrook and Friske (1986) and Friske et al. (1990).*

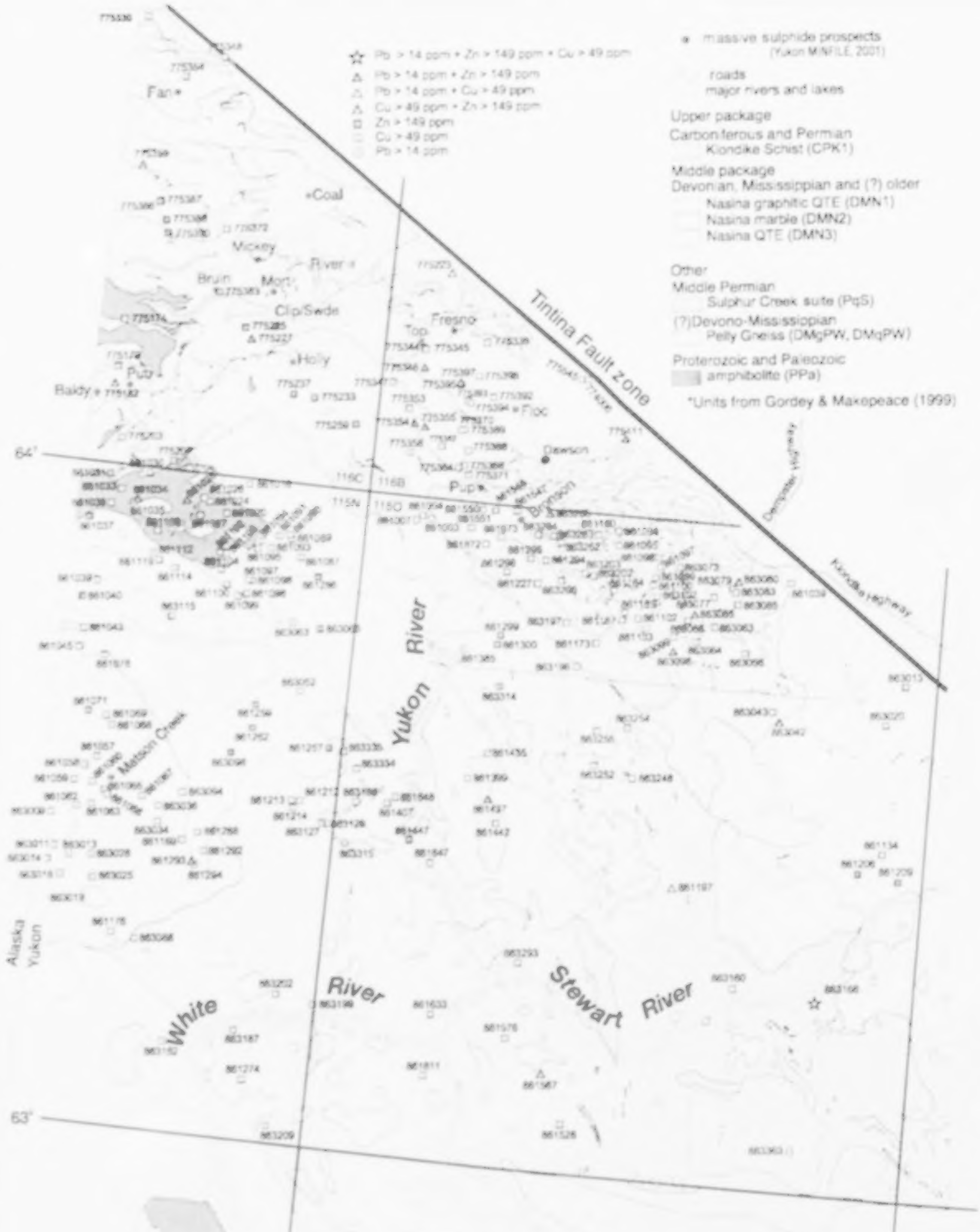

Pb > 14 ppm + Zn > 149 ppm + Cu > 49 ppm
Pb > 14 ppm + Zn > 149 ppm
Pb > 14 ppm + Cu > 49 ppm
Cu > 49 ppm + Zn > 149 ppm
Zn > 149 ppm
Cu > 49 ppm
Pb > 14 ppm
massive sulphide prospects (Yukon MINFILE, 2001)
roads
major rivers and lakes
Upper package
Carboniferous and Permian
Klondike Schist (CPK1)
Middle package
Devonian, Mississippian and (?) older
Nasina graphitic QTE (DMN1)
Nasina marble (DMN2)
Nasina QTE (DMN3)
Other
Middle Permian
Sulphur Creek suite (PqS)
(?)Devono-Mississippian
Pelly Gneiss (DMgPW, DMqPW)
Proterozoic and Paleozoic
amphibolite (PPa)
*Units from Gordey & Makepeace (1999)
Tintina Fault zone
Fan
Coal
Mickey
River
Bruin
Mort
Clip/Swde
Holly
Putz
Baldy
Top
Fresno
Floc
Dawson
Pup
Bonson
Dempster Highway
Klondike Highway
Yukon River
Matson Creek
Alaska
Yukon
White River
Stewart River
116C
116B
115N
115O
64°
63°
140°
138°
10 0 10 20 Kilometres

Figure 30. (caption on previous page)

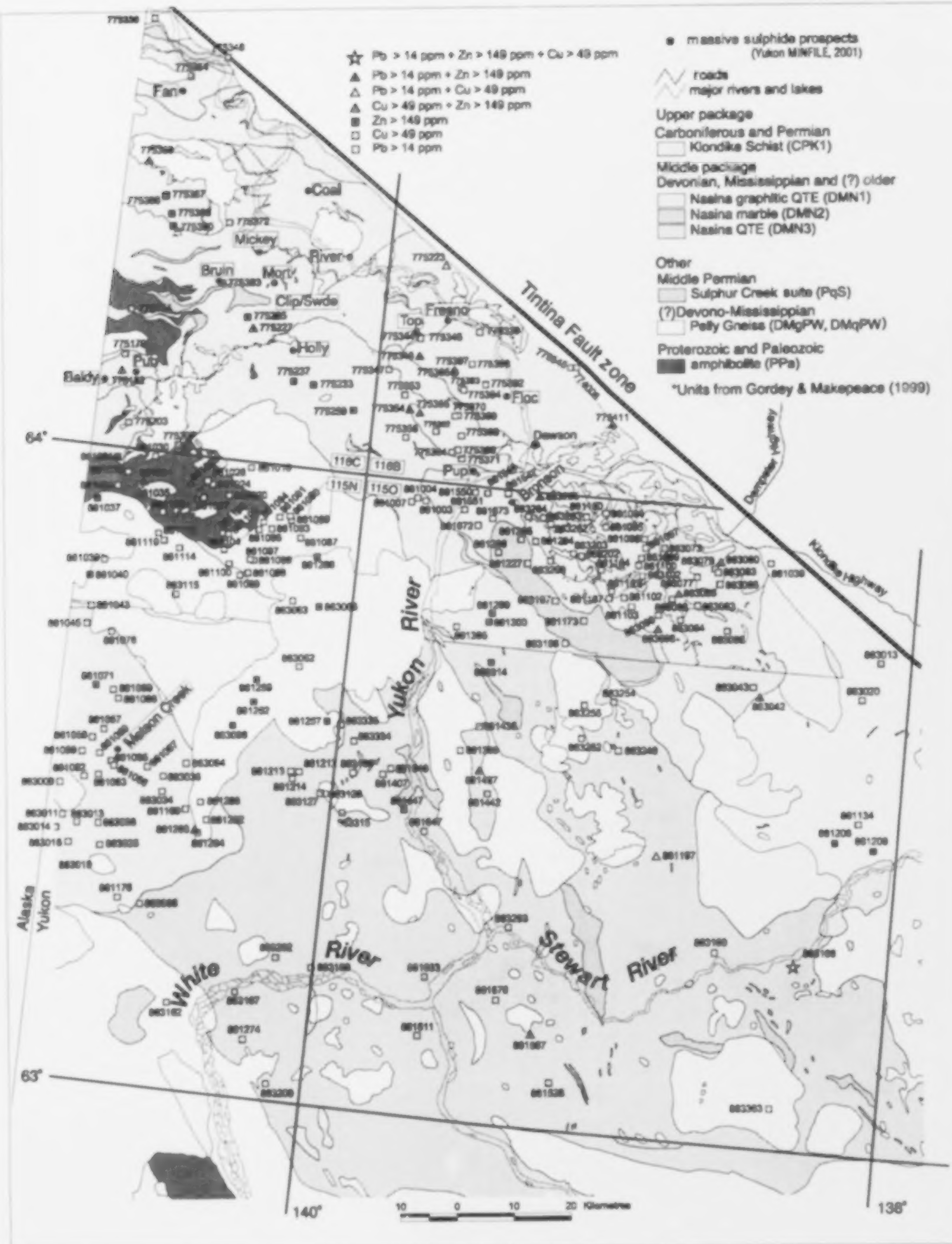

☆ Pb > 14 ppm + Zn > 149 ppm + Cu > 49 ppm
▲ Pb > 14 ppm + Zn > 149 ppm
△ Pb > 14 ppm + Cu > 49 ppm
▲ Cu > 49 ppm + Zn > 149 ppm
■ Zn > 149 ppm
□ Cu > 49 ppm
□ Pb > 14 ppm
● massive sulphide prospects (Yukon MINFILE, 2001)
roads
major rivers and lakes
Upper package
Carboniferous and Permian
Klondike Schist (CPK1)
Middle package
Devonian, Mississippian and (?) older
Nasina graphitic QTE (DMN1)
Nasina marble (DMN2)
Nasina QTE (DMN3)
Other
Middle Permian
Sulphur Creek suite (PqS)
(?)Devono-Mississippian
Pelly Gneiss (DMgPW, DMqPW)
Proterozoic and Paleozoic
amphibolite (PPa)
*Units from Gordey & Makepeace (1999)
Tintina Fault zone
Dempster Highway
Klondike Highway
Fan
Coal
Mickey
River
Bruin
Mort
Clip/Swde
Holly
Pup
Baldy
Top
Fresno
Floc
Dawson
Pup
Bronson
116C
116B
115N
115O
Yukon River
Matson Creek
White River
Stewart River
Alaska
Yukon
64°
63°
140°
138°
10 0 10 20 Kilometres

Figure 30. (caption on previous page)

muscovite schist. Rocks of the Klondike Schist consist of felsic metatuff, rhyolite, mafic metatuff, metagabbro and intercalated metapelite and quartzite (Pride, 1996c). Analyses of quartz-sericite and quartz-muscovite schist from Klondike Schist on the Pup property indicate that they represent calc-alkaline felsic volcanic rocks (Pride, 1996c). These include quartz-phyric rhyolite, massive flow-banded rhyolite, and crystal and ash tuffs. On a Nb/Y versus Zr/TiO_2 diagram the specimens plot within the rhyolite field (ibid.)

Contour soil sampling on Pup detected four areas anomalous in copper-zinc-lead-silver underlain by pyritic quartz-sericite schist and rhyolite with blue quartz phenocrysts (Pride, 1996c). One of the anomalies was sourced to a 1- to 2-cm-thick layer of massive chalcopyrite parallel to layering in felsic metatuff and quartz phyric rhyolite (ibid.).

Fan, Coal, Bruin and Swde

The Fan, Coal, Bruin and Swde areas (Fig. 29) were examined as a follow-up to copper-zinc-lead silt anomalies detected during a 1978 regional geochemical silt (RGS) survey (Geological Survey of Canada, 1978) and/or a 1979 Cominco Ltd. survey (Pride, 1996c).

The **Fan** (Yukon MINFILE, 2001, 116C 172; 64°34'N, 140°50'W; NTS 116C/10) and **Coal** (Yukon MINFILE, 2001, 116C 173; 64°26'N, 140°20'W; NTS 116C/8) properties are underlain by Nasina Assemblage rocks consisting of black metapelite, quartzite and thin felsic metatuffs (Pride, 1996a,b). Those underlying the Fan have been hornfelsed by the Cretaceous Fanning Creek pluton (Pride, 1996a). Contour soil sampling on the Fan detected two areas anomalous in copper-zinc-lead-silver underlain by carbonaceous phyllite and siltstone (Pride, 1996a). Prospecting on the Coal property located float boulders of barite-quartz-magnetite down-slope from a magnetic anomaly (Pride, 1996b). Several conductive ± magnetic features were identified on the Coal property (Pride, 1996b).

The **Bruin** (Yukon MINFILE, 2001, 116C 021/127; 64°19'00"N, 140°41'W; NTS 116C/7) and **Swde** (Yukon MINFILE, 2001, 116C 115; 64°14'N, 140°30'W; NTS 116C/1) occurrences are underlain by graphitic and non-graphitic quartzite, and quartz-muscovite schist of the Nasina Assemblage (Gordey and Makepeace, 1999). One conductive zone with no direct magnetic association, and a single electromagnetic (EM) peak feature with coincident magnetics were detected on Bruin (Woolham, 1995b). No conductors reflecting significant base metal mineralization were identified on the Swde property by a combined helicopter-borne magnetic and electromagnetic survey (Woolham, 1995a).

Base metal occurrences in Permian Klondike Schist

Matson Creek

The Matson Creek prospect (Fig. 29; Yukon MINFILE, 2001, 115N 100; 63°31'22"N, 140°26'23"W; NTS 115N/10) is characterized by coincident lead-zinc-copper geochemical anomalies, electromagnetic (EM) conductors and narrow exhalite horizons with disseminated sulphides and oxides (Haverslew, 1978; Sax and Carne, 1990, Schmidt, 1996c).

The Matson Creek prospect and surrounding area are underlain by metamorphosed intermediate to felsic metavolcanic and metasedimentary rocks of the Klondike Schist (Fig. 30; Haverslew, 1978; Johnston and Mortensen, 1994; Schmidt, 1996c). Moderately south-dipping strata include quartz-sericite schist, calcareous mica schist, chloritic schist, marble, and graphitic schist with generally east-trending, axial planar schistosity (Haverslew, 1978; Schmidt, 1996c). Sax and Carne (1990) state that felsic metavolcanic rocks form a thicker than normal succession in the Matson Creek area and suggest that this may indicate proximity to a felsic volcanic centre.

Drill core and outcrop samples from the Matson Creek property consist primarily of quartz-sericite ± plagioclase-carbonate-biotite/phlogopite-chlorite schists, with accessory pyrite, rutile, sphene and apatite and rare blue quartz 'eyes' (see Appendix VI-3 for complete descriptions). The schists are generally laminated with alternating quartz-carbonate and sericite-rich layers. In general, the more felsic schists (Appendix VI-3: specimens DDH MA92-01-12.6-12.7 m, 40.96-41.05 m, 67.66 m, 82.55 m and 84.42 m, and JH96-40 and 42) are composed of 20-60% quartz, 10-55% feldspar and 5-30% sericite with 0-10% carbonate (ferroan to calcite), trace-2% pyrite, 0-2% limonite, 0-2% sphene/rutile, and sparse 0-5% chlorite and 0-5% biotite. Schists with a more intermediate composition (Appendix VI-3: specimens DDH MA92-01-24.0-24.15 m, 81.0 m and 109.4 m) are composed of approximately 25-45% quartz, 30-45% sericite, 10-15% biotite and minor plagioclase, with 10% carbonate (ferroan to calcite), 1-3% pyrite, 0-10% chlorite, and sparse 0-2% sphene and 0-<1% apatite.

The rocks have been metamorphosed to greenschist facies and are foliated. However, relict textures and minerals indicate that most samples were likely derived from felsic to intermediate volcanic precursors, some of which were quartz- and feldspar-porphyritic (Leitch, 1998). The presence of only minor to trace amounts of plagioclase in some specimens (Appendix VI-3: specimens DDH MA92-02-76.6 m and DDH MA92-03-80.3 m) suggests that they may have siliceous sedimentary precursors (Leitch, 1998).

Surface mineralization at Matson Creek occurs as oxidized, thinly laminated quartz-sericite schist with boxwork cavities. The schist contains elevated levels of lead, zinc, copper, barium and silver (Sax and Carne, 1990; Carne, 1991e). Carne (1991e) suggests that, given the extremely leached nature of the host strata, the elevated metal levels are significant indicators of stratiform base metal mineralization. Fine-grained, disseminated pyrite occurs throughout the schists; locally, pyrite occurs in laminations about 2 mm thick, and in layers with up to 15% disseminated pyrite blebs 2-3 mm in diameter. Additional mineralization occurs within rare, massive, white, foliaform quartz 'veins' up to 1 cm thick that contain minor crystalline galena and sphalerite ± pyrite. Results returned by two samples of surface mineralization are in Appendix VI-2. Sample WZ-14 is a 0.75-m chip sample collected across limonitic quartz-sericite-biotite schist that is sandwiched between layers of quartz-muscovite-chlorite schist at least 0.5 m thick. WZ-15 is a 0.5-m chip sample across the chloritic schist, which contains about 10% goethite and <1% disseminations and coatings of native copper.

Drilling intersected narrow, laminate concentrations of disseminated galena with variably oxidized and leached pyrite and sphalerite within siliceous ankerite or ferroan dolomite intervals interpreted as distal exhalite horizons (Carne, 1993a). The ankerite/ferroan dolomite intervals occur at four stratigraphic positions at, or near, the transition from intermediate to felsic metaflows or tuffs (Carne, 1993a). Drilling traced the horizon over a 1 km distance. The best intersection was a 4.1-m-thick interval of 0.08% Zn, 1.10% Pb, 0.09% Cu and 2.7 g/t Ag (Carne, 1993a); however, this intersection is highly oxidized and leached suggesting that the original metal grades could have been significantly higher.

Soil geochemical surveys have outlined a 7-km-long east-trending lead anomaly, with coincident but lower zinc and copper values (Schmidt, 1996c; Sax and Carne, 1990; Carne 1991e; Carne 1993a). The high lead versus copper and zinc values in soils probably reflect the relatively higher geochemical mobility of copper and zinc in highly weathered terranes, rather than reflecting metal ratios of primary bedrock mineralization (Sax and Carne, 1990; Carne 1991e; Carne 1993a). Although down-slope transport of rubble is a complicating factor in interpreting the soil geochemical data, it appears that the anomalies parallel compositional layering in the underlying bedrock. The strongest geochemical responses coincide with a 100-m-wide zone of recessive, limonitic quartz-sericite schist (Carne, 1993a). The soil results support those from stream sediment samples that returned values as high as 140 ppm Pb, 1630 ppm Zn and 120 ppm Cu (Haverslew, 1978).

Geophysical surveys involving Turam techniques indicate an overall weak geophysical response with no significant anomalies. Haverslew (1978) suggests this indicates disseminated mineralization. A later MaxMin I-9 horizontal-loop electromagnetic (HLEM) survey identified two weak anomalies on the west side of the property (Carne, 1993a).

Baldy (Bal) and Pub

The **Baldy** (Fig. 29; Yukon MINFILE, 2001, 116C 133; 64°06'10"N, 140°59'01"W; NTS 116C/2) and **Pub** (Fig. 29; Yukon MINFILE, 2001, 116C 112; 64°07'10"N, 140°52'28"W; NTS 116C/2) occurrences are located about 70 km west of Dawson City near the Yukon-Alaska border approximately 2 km north of the Top of the World Highway. The Pub prospect is about 4 km northeast of, and along strike with the Baldy occurrence.

The Pub and Baldy properties are underlain by Permian rocks of the Klondike Schist (Fig. 30; Johnston and Mortensen, 1994). A northerly dipping, 2000-m-thick sequence of metavolcanic rocks that consist of pyritic quartz-muscovite schist, quartz and/or feldspar augen schist and chloritic schist with minor graphitic quartz-muscovite schist underlie the properties (Carne, 1991d; Schmidt, 1996a,b). In general, this sequence of metavolcanic rocks is dominated by chloritic schists at the structural base with more sericitic schists occurring towards the top (Carne, 1991d). Carne (1993b) interprets the sequence to represent a transition from mafic or intermediate volcanism to felsic volcanism.

On the Baldy property, in the bed of Hall Creek, disseminated sphalerite, chalcopyrite, galena and minor pyrite occur along foliation planes within schists in a siliceous interval at or near the contact between chloritic and sericitic parts of the Klondike Schist (Carne, 1991d;

1993b). A specimen of quartz-sericite schist with bands of disseminated galena-sphalerite-pyrite mineralization returned 3.43% Pb, 8.09% Zn, 0.20% Cu, 41.0 g/t Ag and 195 ppb Au (Carne, 1993b). Similar mineralization occurs on the Pub property where leached pyrite-sphalerite-chalcopyrite laminations in schistose metavolcanic rocks and disseminated sphalerite, galena, chalcopyrite and pyrite in siliceous schist occur at the approximate contact between chloritic and sericitic layers (Haverslew, 1978). Lead isotope analysis of galena from the Baldy occurrence indicated a middle to Upper Permian model age (Carne, 1993b) based on the shale model of Godwin and Sinclair (1982).

Soil sampling on the properties outlined lead-zinc-copper ± silver anomalies that correlate with exposures of quartz-sericite schist with intensely oxidized and leached sulphides (Haverslew, 1978; Schmidt, 1996a,b). Anomalous values in soils for lead, silver, copper and zinc for the Pub and Bal prospects are 100-200, 0.2 to 0.8, 25-100 and 100-200 ppm, respectively (Carne, 1991d, 1993b). Background values are 10-25, <0.2, 10-15 and 50-75 ppm, respectively (ibid.). Stream sediment samples are moderately anomalous in zinc and lead, and locally weakly anomalous in copper (Haverslew, 1978).

A MaxMin I-9 horizontal-loop electromagnetic (HLEM) geophysical survey over the Baldy property detected a single weak conductor that does not appear to be associated with any geochemical anomalies (M.A. Power in Carne, 1993b).

Bronson

The Bronson occurrence (Fig. 29; Yukon MINFILE, 2001, 115O 113; 63°58'N, 139°29'W; NTS 115O/14) is on the flank of Mount Bronson south of Bryant Creek, approximately 11 km south of Dawson City. It occurs in an area marked by anomalous copper, lead, zinc and silver soil and silt geochemistry (Olfert, 1981).

The area is underlain by a northwest-trending belt of locally rusty-weathering Klondike Schist. In the vicinity of the Bronson occurrence Klondike Schist includes quartz- and feldspar-augen-bearing quartz-muscovite schist and rusty-weathering muscovite-quartz schist (Mortensen, 1996), which were interpreted to be felsic metavolcanic rocks (Fig. 30; Olfert, 1981; Mortensen, 1996).

Soil sampling has defined a coincident lead-silver ± copper ± zinc geochemical anomaly 2000 m long by 150 to 400 m wide that appears to trend parallel to the underlying stratigraphy (Olfert, 1981). Anomalous lead, silver, copper and zinc in soil values range from 50-150, 1.0-3.0, 50-150 and 100-300 ppm, respectively. Background values for lead, silver, copper and zinc are 10-25, <0.4, 10-20 and 50-60 ppm, respectively.

Quartz-carbonate vein float, with minor galena mineralization, has been found just west of the soil anomaly (Olfert, 1981). In addition, there are boulders of schist containing stringers and disseminations of pyrite, chalcopyrite and galena (Mortensen, 1986). The stringer mineralization gives a Permian lead isotopic model age and is interpreted by Mortensen (1996) to be syngenetic VMS-style mineralization.

Floc

The Floc property (Fig. 29; Yukon MINFILE, 2001, 116B 092; 64°08'N, 139°45'W; NTS 116B/4) is underlain dominantly by Klondike Schist with lesser Nasina Assemblage (Pride, 1996d). Lead isotope analysis of mineralization and two soil samples anomalous in Pb indicates a Permian age for the mineralization (ibid.) based on the shale model of Godwin and Sinclair (1982). Klondike Schist consists of felsic metatuff, metarhyolite, mafic metatuff, metagabbro and intercalated metapelite and quartzite (ibid.). Nasina Assemblage consists of black metapelite, quartzite and thin felsic metatuffs (ibid.). This area was examined as a follow-up to copper-zinc-lead silt anomalies detected during a 1978 regional geochemical silt (RGS) survey (Geological Survey of Canada, 1978), and/or a 1979 Cominco Ltd. survey (Pride, 1996d).

Lithogeochemical analyses (Pride, 1996d) of foliated quartz-muscovite and quartz-sericite schist samples from the Floc property indicate that they represent primarily felsic volcanic rocks. These include rhyolite, ash tuff and crystal tuff. Analyses of chlorite-biotite schists show that they represent mafic volcanic rocks. The rocks include alkaline basalt, lapilli tuff and gabbroic sills. On a Nb/Y versus Zr/TiO_2 diagram most of the specimens plot within the rhyolite and rhyodacite/dacite fields with a few samples plotting in the trachyandesite, andesite and alkaline basalt fields.

Contour soil geochemical sampling on Floc detected three areas anomalous in copper-zinc-lead-silver. One of these was sourced to finely disseminated chalcopyrite, galena and sphalerite (0.14% Cu, 1.7% Pb, 0.71% Zn and 65 ppm Ag over 0.3 m) along foliation in felsic metatuff (Pride, 1996d).

No geophysical conductors reflecting significant base metal mineralization were identified on the Floc property by a combined helicopter-borne magnetic and electromagnetic survey flown over part of the property (R.W. Woolham in Pride, 1996d). Magnetic highs detected during this survey correlate with Tertiary dykes (ibid.).

Base metal occurrences in rocks of unknown affinity (either Klondike Schist or Nasina Assemblage)

Top

The Top property (Fig. 29; Yukon MINFILE, 2001, 116B 041; 64°11'N, 139°50'W; NTS 116B/4) is located 25 km northwest of Dawson City. It was staked in 1995 for Nordac Resources Ltd. to cover strong multi-element stream sediment geochemical anomalies resulting from surveys conducted previously in the area by Archer Cathro and Associates (1981) Ltd. (Carne, 1996c; Carne, 1999). The property is underlain by a sequence of quartz-muscovite-chlorite schist, chlorite schist, quartz-feldspar-amphibole gneiss, metagabbro, micaceous quartzite and marble (Mortensen, 1988) belonging to either the Nasina Assemblage or the Klondike Schist. Trenching on the property exposed a gently to moderately southwest-dipping sequence of metavolcanic and metasedimentary rocks that include a metaandesitic to metarhyolitic succession capped by a 0.7-m-thick magnetite, barium, manganese and base metal-rich horizon (Carne, 1999). The magnetite-rich horizon is overlain by graphitic phyllite, which in turn is overlain by a sequence of metarhyolite similar to that below the mineralized horizon.

The magnetite-rich horizon, which is exposed in road cuts at the southeast end of the claim block, contains anomalous levels of copper, lead, zinc, silver and cadmium. It is interpreted by Carne (1999) to be a highly oxidized and leached exhalite horizon likely related to VMS mineralization.

Soil and silt samples from the property returned highly anomalous values of copper, lead and/or zinc (Carne, 1996c). Threshold values used in soils were 25 ppm Cu, 50 ppm Pb and 100 ppm Zn. The soil anomaly forms a discontinuous, linear, north- to northwest-trending zone that is generally conformable with foliation and overlies the stratigraphic interval believed to be prospective for VMS mineralization (Carne, 1999). The stream sediment geochemical anomalies are thought to reflect a mineralized source within the sequence of intermediate to felsic metavolcanic rocks that underlies the magnetite-rich horizon.

Fresno

The Fresno property (Fig. 29; Yukon MINFILE, 2001, 116B 076; 64°15'N, 139°45'W; NTS 116B/5) was staked for Nordac Resources Ltd. to cover a multi-element geochemical anomaly, at least 1 km long, that was revealed in surveys conducted in the area by Archer Cathro and Associates (1981) Ltd. in the 1970s and 1980s (Carne, 1996a). The property is underlain by relatively flat-lying quartz-muscovite-chlorite schist, chlorite schist, quartz-feldspar-amphibole gneiss, metagabbro, micaceous quartzite and marble (Mortensen, 1988; Carne, 1996a; Gordey and Makepeace, 1999).

River

The River property (Fig. 29; Yukon MINFILE, 2001, 116C 045; 64°19'N, 140°10'W; NTS 116C/8) was staked for Nordac Resources Ltd. to cover galena, sphalerite and pyrite mineralization hosted by siliceous quartz-muscovite schist along the banks of the Yukon River (Carne, 1996b). The property is underlain by shallowly west-dipping quartz-muscovite-chlorite schist, chlorite schist, quartz-feldspar-amphibole gneiss, metagabbro, micaceous quartzite and marble (Mortensen, 1988; Carne, 1996a; Gordey and Makepeace, 1999). Concordant layers and lenses of massive pyrite up to several centimetres thick occur near the contact of a metavolcanic unit with underlying marble and quartzite (Carne, 1996b). Specimens of pyritic float and bedrock returned weakly anomalous values of copper, lead and zinc (Carne, 1996b). A multi-component electromagnetic (EM) and magnetic airborne geophysical survey was flown over the River property and coincident EM and magnetic anomalies were detected along the projected trend of the prospective horizon (Carne, 1996b).

EXPLORATION TECHNIQUES

The Dawson area, west of the Tintina Fault, largely escaped Pleistocene glaciation (Hughes et al., 1969; Hughes, 1987; Duk-Rodkin, 1996). It is therefore deeply weathered and covered by a thick mantle of soil and vegetation. This area is also underlain by discontinuous permafrost. At the surface, sulphides are strongly oxidized and leached, and marked only by boxwork textures. In drill holes, oxidation to approximately 80 m depth is common. This presents problems for traditional geochemical prospecting using soil samples. For example, in some locations anomalous areas of metals outlined by soil sampling are the result of hydromorphic and/or detrital dispersion.

Stream sediment and soil sampling

Geochemical results reported in various assessment reports for VMS mineral occurrences in the Dawson area are summarized in Tables 2 and 3. Table 2 is a summary of results returned by soil samples from mineral occurrences hosted within Devono-Mississippian rocks. Table 3 is a summary of results returned by soil samples from mineral occurrences hosted by probable Carboniferous to Permian rocks.

Anomalous values in soil samples were generally an order of magnitude greater than those for stream sediment samples. For example, on the Pup property, a stream sediment sample collected 300 m downstream from a 250-m-long soil anomaly returned values of 17, 26 and 77 ppm Cu, Pb and Zn, respectively; however, the soil anomaly returned values of up to 535, 137 and 156 ppm, respectively (Pride, 1996c). On the Floc property a stream sediment sample collected 2 km downstream from anomalous soils returned values of 12 and 43 ppm Cu and Pb, respectively; however, the soil samples returned values of up to 134 and 980 ppm respectively (Pride, 1996d).

An examination of regional geochemical silt (RGS) sample data for the Dawson area shows that many creeks draining areas of Klondike Schist contain elevated levels of lead (Fig. 30; for complete information see Friske et al., 1990, Geological Survey of Canada, 1978; Hornbrook and Friske, 1986). For example, creeks draining to the southwest of the Matson Creek property contain Pb values of 15 to 49 ppm, and those draining Mount Bronson contain Pb values of 15 to 44 ppm. Creeks draining areas of Nasina Assemblage rocks are not as consistently enriched in metals as those draining the Klondike schist, but they locally contain elevated levels of lead, zinc and/or copper (Fig. 30).

Biogeochemical sampling

It is, in some cases, useful to use the vegetative cover (for example, bark or twigs) as a sampling medium rather than the soil in locations like the Dawson area (Dunn, 1995). To test the effectiveness of biogeochemical sampling in exploration for VMS deposits in this area, the Matson Creek property was selected for an orientation biogeochemical survey. At each site eight twigs, each about 25 cm long and of consistent diameter were collected from black spruce trees (see Hunt et al., 1997 for details). This property was chosen in part because existing soil geochemical data could be used as a comparison to the biogeochemical results.

The results, in Figure 31, show that base metal biogeochemical and soil anomalies are generally coincident. The results also show that copper, zinc, silver, cadmium, and to a lesser extent lead, serve as the best guides to mineralization (see Hunt et al., 1997 for details). However, the survey also demonstrated that biogeochemical anomalies, at least in the Matson Creek area, tend to be subtle, and therefore, could easily be overlooked. However,

Table 2. *Lead, zinc and copper values in soils from VMS mineral occurrences hosted by Devono-Mississppian rocks in the Dawson area. Results are summarized from Carne (1991a,b,c, 1996a,c, 1999), Schmidt (1996d), Olfert (1979, 1980) and Pride (1996a,c,d).*

Element	Range	Anomalous	Highly anomalous
Lead (ppm)	<2 to 3140	>50	>150
Zinc (ppm)	<1 to 906	>100	>200
Copper (ppm)	Trace to 680	>30	>100

Table 3. *Lead, zinc and copper values in soils from VMS mineral occurrences hosted by probable Carboniferous to Permian rocks in the Dawson area. Results are summarized from Carne (1991d,e, 1993a,b), Olfert (1981), Sax and Carne (1990), Haverslew (1978) and Pride (1996d)*

Element	Range	Anomalous	Highly anomalous
Lead (ppm)	2 to 2350	>50	>150
Zinc (ppm)	8 to 1555	>100	>200
Copper (ppm)	5 to 365	>25	>100

Figure 31. *Copper, lead and zinc biogeochemical (~8 year old twigs) and soil sampling results for the Matson Creek property. Soil sample results are from Haverslew (1978).*

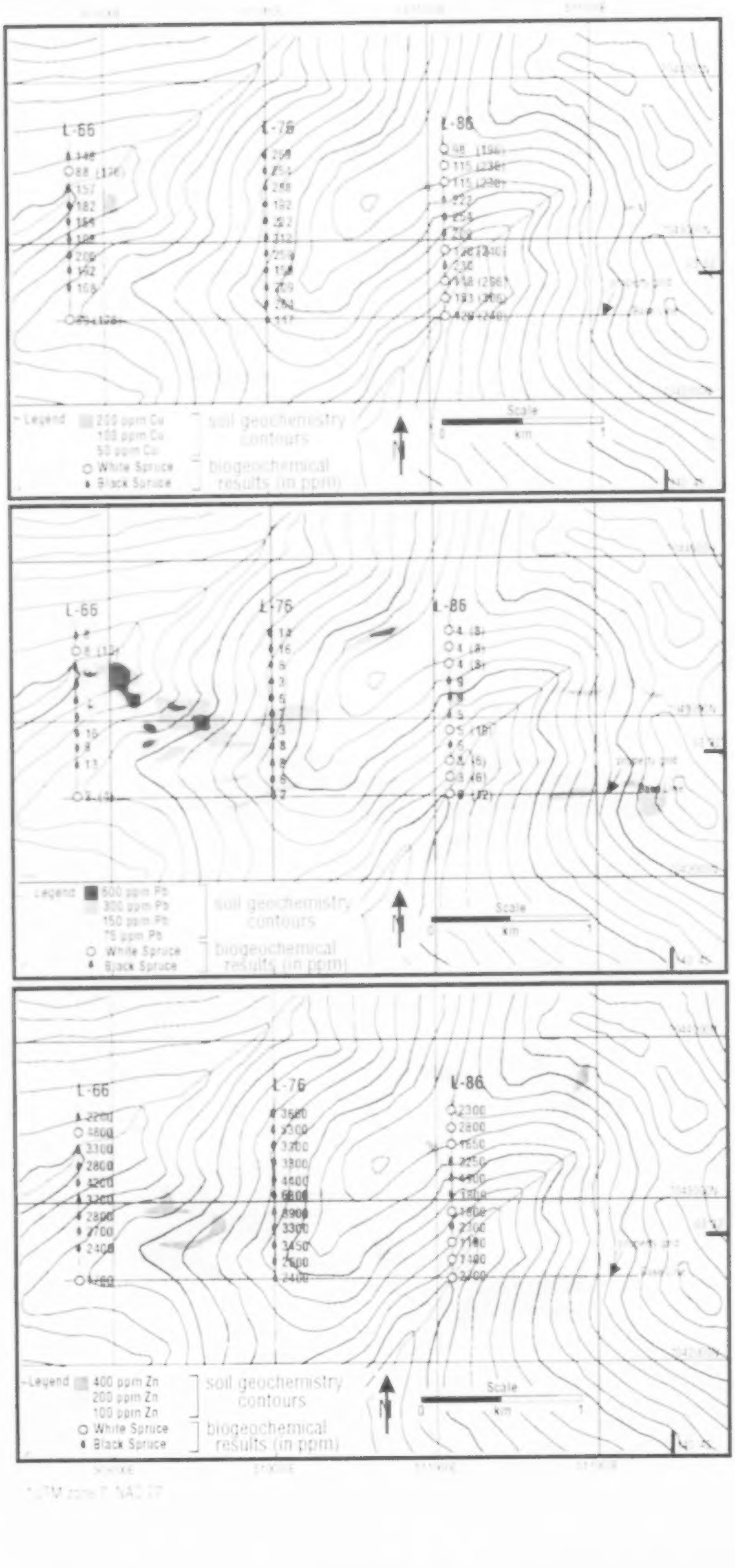
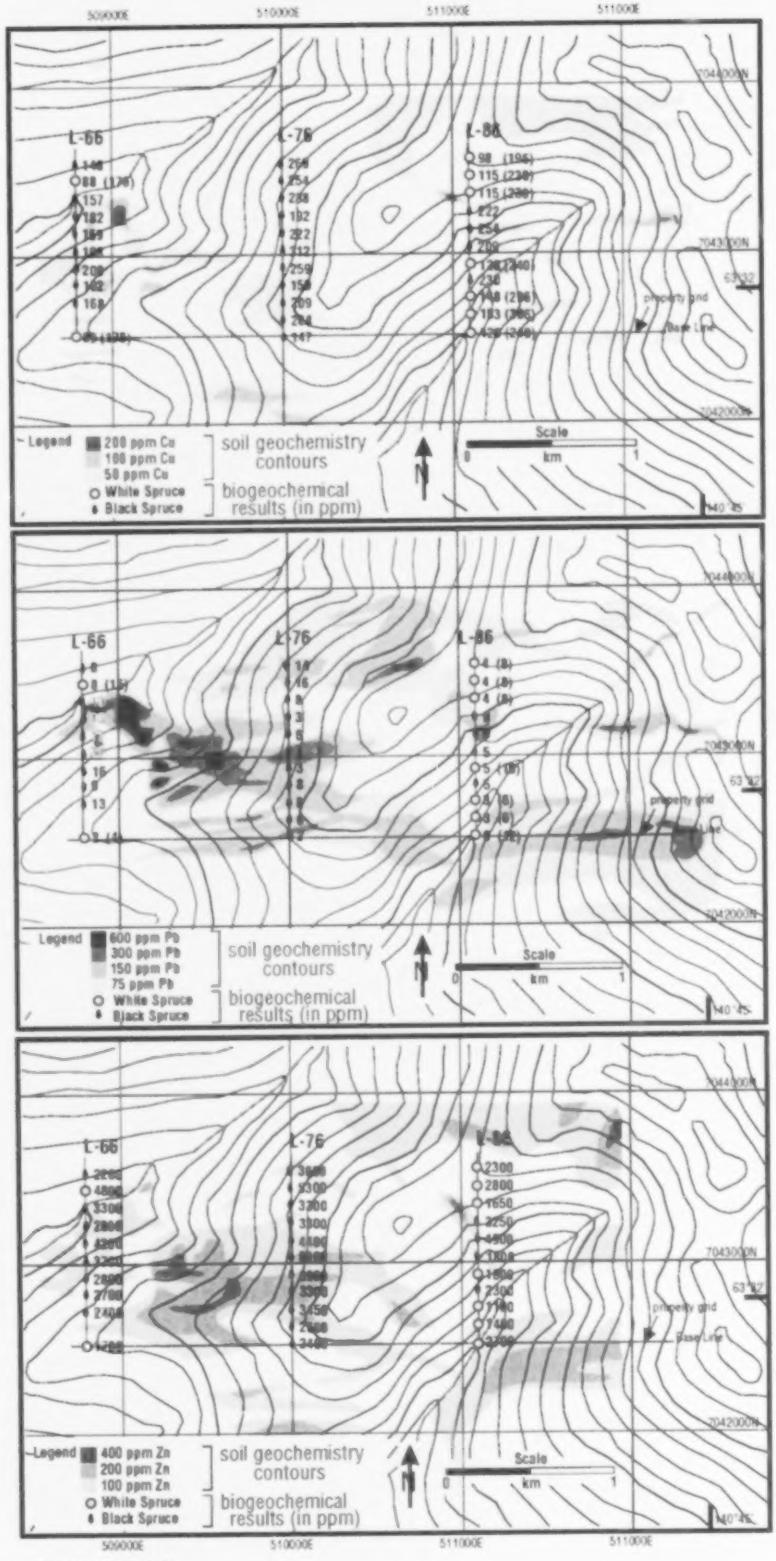

L-66
L-76
L-86
Legend
200 ppm Cu
100 ppm Cu
50 ppm Cu
soil geochemistry contours
White Spruce
Black Spruce
biogeochemical results (in ppm)
Scale
0
km
1
600 ppm Pb
300 ppm Pb
150 ppm Pb
75 ppm Pb
400 ppm Zn
200 ppm Zn
100 ppm Zn
property grid
UTM zone 7, NAD 27

Figure 31. *Copper, lead and zinc biogeochemical (~ 8 year old twigs) and soil sampling results for the Matson Creek property. Soil sample results are from Haverslew (1978).*


509000E
510000E
511000E
511000E
7044000N
7043000N
7042000N
63°32'
140°45'
L-66
L-76
L-86
property grid
Base Line
Legend
200 ppm Cu
100 ppm Cu
50 ppm Cu
White Spruce
Black Spruce
soil geochemistry contours
biogeochemical results (in ppm)
Scale
0
km
1
N
600 ppm Pb
300 ppm Pb
150 ppm Pb
75 ppm Pb
400 ppm Zn
200 ppm Zn
100 ppm Zn

*UTM zone 7, NAD 27

this technique has been used successfully in other parts of Canada. For example, samples from black spruce (twigs, outer bark and needles) record a 400 x 300 m zone of multi-element enrichment over the western edge of the deeply buried Chisel North massive sulphide deposit in the Snow Lake area of Manitoba (Fedikow and Dunn, 1996). This method thus provides a potentially valuable aid to exploration for base metals in large prospective areas of poor outcrop.

Geophysics

Multicomponent electromagnetic and magnetic airborne geophysical surveys and ground geophysical surveys have been used in the Dawson area to outline prospective horizons and zones on several properties (see references for individual properties described above).

SUMMARY OF VMS OCCURRENCES IN THE YUKON-TANANA TERRANE IN ALASKA

The Yukon-Tanana Terrane (YTT), based on stratigraphic similarities and sparse age data, continues westward from the Dawson area across the border into Alaska where it underlies a large part of the east-central area of the state north of the Denali Fault (Fig. 2; Mortensen, 1992a; Lange et al., 1993; Dusel-Bacon et al., 1998). Mortensen (1992a) indicates that most of the criteria used to characterize the YTT in the Yukon also apply in east-central Alaska and that the similarities between the various sub-terranes outweigh the differences. In the portion of the YTT south of the Tanana River (Fig. 2) stratigraphic sequences have been mapped that are comparable to those in the Dawson and Finlayson Lake areas of the Yukon (Mortensen, 1992a). The main points of similarity include abundant Devonian to mid-Mississippian metavolcanic rocks overlying quartzo-feldspathic and pelitic metasedimentary rocks and carbonate, which are all intruded by Devono-Mississippian granitoids (Mortensen, 1992a). Also, based on the age of a newly dated rhyolite, Dusel-Bacon et al. (1998) suggest that the Klondike Schist, the uppermost part of the YTT in the Dawson area, continues westward into the Liberty area of Alaska (Fig. 2). For further discussion see Dusel-Bacon et al. (1998), Newberry et al. (1997) and Lange et al. (1993). In addition, lead isotopic signatures from Devonian to Mississippian VMS deposits and occurrences in the eastern Alaska Range are similar to those from Devonian massive sulphide deposits found in the Kootenay Terrane in southern British Columbia (Fig. 2; Lange et al., 1993), which has been correlated with the YTT by Wheeler and McFeely (1987).

Within the Alaskan portion of the Yukon-Tanana Terrane, VMS mineralization is hosted primarily by Devono-Mississippian intermediate to felsic submarine metavolcanic and metasedimentary rocks (Lange et al., 1993). The deposits and occurrences lie within the Delta, Trident Glacier, Bonnifield and Kantishna districts which form a belt more than 150 km long along the southern margin of the terrane north of the Denali Fault (Fig. 2). The Delta district lies at the southeast end of the belt and contains most of the known VMS occurrences (Lange et al., 1993; Newberry et al., 1997). The Bonnifield and Trident Glacier districts are northwest of the Delta district (Fig. 2) and host fewer VMS occurrences. The Kantishna district forms the northwestern end of the VMS belt, but is located largely within Denali Park.

VMS mineralization hosted in probable YTT rocks also occurs in southeast Alaska (Fig. 2) near Ketchikan (Moth Bay deposit) and in the Sumdum Glacier mineral belt (Sumdum, Tracy Arm and Sweetheart Ridge occurrences; Newberry et al., 1997) about 80 km south-southeast of Juneau. In eastern Alaska, about 100 km west of Dawson, Yukon, VMS mineralization is hosted by similar rocks in the Liberty area (Fig. 2; Dusel-Bacon et al., 1998).

The geologic setting, structure, petrology and geochemistry of the various VMS deposits and occurrences (Table 5) within the main districts, along with an interpretation and discussion of their genesis, summarized in Lange et al. (1993) and Newberry et al. (1997), are condensed below.

DELTA DISTRICT

The Delta district covers over 800 km^2 and hosts at least 35 massive sulphide occurrences that are distributed along four mineral trends (Table 5: PP-LZ, DD-Rum, DW-LP and Trio) within the Jarvis Creek Glacier subterrane of the YTT (Lange et al., 1993; Newberry et al., 1997). The PP-LZ trend is hosted by metasedimentary rocks, the DD-Rum trend is hosted by metavolcanic rocks, and the DW-LP and Trio trends are hosted by schist of unknown protolith (Lange et al., 1993). The mineral trends range from 5 to 32 km in length and are subparallel to northwest-striking, southwest-dipping regional structures and units (Lange et al., 1993). Most of the occurrences are hosted by rhyolitic metavolcaniclastic units that are dominated by felsic quartz-eye metatuff intruded by (meta)gabbro sills. The deposits and occurrences consist of layers and zones with varying amounts of massive to disseminated pyrite and pyrrhotite, and lesser amounts of chalcopyrite, galena, sphalerite and arsenopyrite in a gangue of carbonate, quartz and mica (ibid.). The larger deposits range from 1.0 to 5.2 million tonnes with combined grades of 5.6% Cu+Pb+Zn, and Ag and Au contents of 56 and 1.9 g/t, respectively (ibid.). Massive sulphide mineralization that is closely associated with strongly altered metavolcanic rocks in the central part of the district (DD-Rum trend) is generally thick, lensoid and enriched in gold compared to mineralization in other trends (ibid.). In contrast, mineralization in the PP-LZ trend that is hosted by weakly altered metasedimentary rocks is typically sheet-like, thin, finely banded and enriched in silver (ibid.).

The largest sulphide body in the belt is within the DW-LP trend. It is a single massive sulphide sheet 1.8 x 2.5 km in area and 0.12 to 12 m thick that has been cut into 5 pieces (PP-2, LP, Middle, DW and Valley) by block faulting (ibid.). Resource estimates for the five blocks are as follows: PP2 – 2.3 Mt of 0.46% Cu, 2.93% Zn, 1.23% Pb, 34.9 g/t Ag, 0.25 g/t Au; LP – 1.1 Mt of 0.4% Cu, 3.69% Zn, 1.54% Pb, 51.0 g/t Ag, 1.73 g/t Au; Middle – 4.7 Mt of 0.46% Cu, 3.54% Zn, 1.36% Pb, 42.3 g/t Ag, 1.08 g/t Au; DW – 1.2 Mt of 0.93% Cu, 1.74% Zn, 1.15% Pb, 20.4 g/t Ag, 0.34 g/t Au; and Valley – 0.9 Mt of 0.26% Cu, 3.45% Zn, 0.46% Pb, 19.8 g/t Ag, 0.51 g/t Au (Newberry et al., 1997). The dominant sulphides are pyrite, pyrrhotite, chalcopyrite, sphalerite and galena; gold is associated with chalcopyrite and pyrite (ibid.). The principal gangue minerals are chlorite, quartz and carbonate. The mineralization is hosted by pervasively sericite-chlorite-carbonate-pyrite-altered metavolcaniclastic rocks (Lange et al., 1993; Newberry et al., 1997). Hanging wall rocks to the sulphide horizon are mylonitic quartz-sericite-pyrite schists. Footwall rocks are strongly sulphidized chloritic schists 15 to 30 m thick above a footwall metagabbro sill (Newberry et al., 1997).

Host rocks to the VMS mineralization in the Delta district are lithologically similar to those in the Finlayson Lake district with the exception of metagabbro sills, which are less abundant in the Finlayson Lake district. The deposits discovered to date in the Delta district are most similar to Kudz Ze Kayah and Wolverine in that they are copper-zinc-silver-gold-rich deposits hosted primarily by Devono-Mississippian felsic metavolcanic rocks. No mafic metavolcanic-hosted copper-cobalt-gold deposits similar to Fyre Lake or Ice have been reported.

TRIDENT GLACIER DISTRICT

Massive sulphide mineralization in the Trident Glacier district occurs intermittently over a 25-km-long northwest-trending belt located about 100 km northwest of the Delta district (Fig. 2; Lange et al., 1993). Mineralization in

Table 4. *VMS mineralization in YTT rocks in Alaska. Information from Lange et al. (1993), Newberry et al. (1997) and Dusel-Bacon et al. (1998).*

REGION	**AREA**	**VMS DEPOSITS OR OCCURRENCES**
East-central Alaska	Delta district	
	• PP-LZ trend	LPP, PPD, UPP, LZ East, LZ, RC East and RC
	• DD-Rum trend	LBB, Rum South, Rum North, Lower Rum, DDS, DDX, DDY and DDN
	• DW-LP trend	PP-2, LP, Middle, DW and Valley
	• Trio trend	HND, Trio East, Trio, Trio North, Trio West, MB, PGX, PG Discovery and PGW
East-central Alaska	Trident Glacier district	at least 11 occurrences including the Miyaoka deposit
East-central Alaska	Bonnifield district	26 prospects including WTF (Dry Creek), Red Mountain and Anderson Mountain
Southeast Alaska	Sumdum Glacier mineral belt	Sweetheart Ridge prospect, Tracy Arm prospect and Sumdum Glacier prospect
Southeast Alaska	Moth Bay	Moth Bay deposit
Eastern Alaska	Liberty	unnamed prospects

the Trident Glacier district is similar to that in the Delta district, but the deposits tend to be smaller and of lower grade (Lange et al., 1993). The mineralization is hosted within a complexly deformed, thinly layered sequence of predominantly muscovite- and/or chlorite-quartz and quartz-feldspar augen schist, chlorite schist, and calc-schist (Lange et al., 1993). The sulphide bodies are commonly spatially associated with occurrences of chlorite-epidote-actinolite schist and marble in the above sequence (ibid.). The mineralization generally contains variable amounts of chalcopyrite ± sphalerite, galena, pyrite and arsenopyrite in massive pyrrhotite, in a gangue that includes quartz, chlorite, epidote, biotite, calcite, actinolite and carbonaceous material (ibid.).

The Trident Glacier district includes the Miyaoka deposit which is spatially associated with thinly bedded intermediate to mafic metavolcanic rocks and marble within a dominantly felsic metavolcanic package (Lange et al., 1993). Mineralization in the deposit is made up of sulphide lenses and pods up to 1 m thick composed of pyrrhotite with lesser chalcopyrite, and minor pyrite and sphalerite (Lange et al., 1993).

BONNIFIELD DISTRICT

The Bonnifield district lies about 50 km northwest of the Trident Glacier district and contains at least 26 VMS prospects (Fig. 2; Newberry et al., 1997). The largest occurrence in the Bonnifield district is the WTF (now known as the Dry Creek property - owned by Grayd Resource Corporation), hosted by sericite-talc-altered metatuff within and immediately below carbonaceous slate (Newberry et al., 1997). This location corresponds to the transition from volcanic and volcaniclastic deposition to sedimentary deposition (Atna Resources Ltd., 1999).

Mineralization occurs on both limbs of a broad, westerly plunging, east-west-striking synform that transects Dry Creek. The WTF zone occurs on the northern limb, and the Red Mountain area is on the southern limb 3 km to the south. In the WTF zone mineralization occurs as three distinct lenses from 0.3 to 4.6 m thick consisting of pyrite, sphalerite and galena with minor chalcopyrite and tetrahedrite in a gangue of silica, carbon and mica (Newberry et al., 1997). The Red Mountain area contains two massive sulphide horizons within a 1700-m-thick section of intensely altered felsic metavolcanic and associated metasedimentary rocks (Grayd Resource Corporation, 2001).

OTHER

Sumdum Glacier Mineral Belt

Stratiform, probable VMS prospects occur in amphibolite grade metamorphic rocks between Tracy Arm and the southern end of southeast Alaska (Newberry et al., 1997), about 80 km south-southeast of Juneau (Fig. 2). These rocks were interpreted by McClelland et al. (1991) as Yukon-Tanana Terrane. Based on recent mapping and U-Pb analyses they are most likely Devonian in age (Gehrels et al., 1992). The probable VMS prospects occur near the Coast Range batholith in a 1- to 2-km-wide, 50-km-long belt termed the Sumdum Glacier mineral belt (Newberry et al., 1997). The belt contains the copper-zinc ± lead Sweetheart Ridge, Tracy Arm and Sumdum Glacier prospects (Fig. 2), which are hosted by biotite-plagioclase-hornblende schist and gneiss with interlayers of quartzo-feldspathic gneiss and quartz-muscovite schist that probably represent metabasaltic and metarhyolitic rocks (Kimball et al., 1984).

Ketchikan Area

The Moth Bay deposit, a historic copper-zinc mine, is located about 18 km southeast of Ketchikan (Fig. 2). Sulphide mineralization occurs at the contact between amphibolite facies quartz-muscovite-calcite and quartz-biotite-feldspar-muscovite schist within a roof pendant near the western margin of the Coast Range batholith (Newberry et al., 1997). This pendant may also be part of the Yukon-Tanana Terrane. The immediate host rocks to the deposit are metamorphosed rhyolitic and mafic volcanic rocks, volcaniclastic rocks and breccias. The mineralization is made up of three subparallel sulphide beds and pods up to 4 m thick that consist of recrystallized, layered to massive, coarse-grained pyrite, sphalerite, chalcopyrite, pyrrhotite, and lesser galena, bornite, magnetite and covellite in a gangue of quartz and calcite.

Liberty Area

Stratiform zinc-lead-silver mineral occurrences hosted by rocks that may be correlative with the Devono-Mississippian Nasina Assemblage (Mortensen, 1988; Foster, 1992) are described by Dusel-Bacon et al. (1998) in the Liberty area of Alaska (Fig. 2), which is about 100 km west of Dawson, Yukon. This mineralization is described as similar to that in the Dawson area (for example, the Mort occurrence). In addition, geochemical sampling by Asher (1970) indicates that sediments from Poker, Davis and Younger creeks, which drain westward across the Yukon-Alaska border near the town of Boundary contain elevated levels of Cu, Pb, Zn and Ba.

SOUTH-CENTRAL YUKON AND NORTHERN BRITISH COLUMBIA

The Teslin-Rancheria area and adjacent parts of northern British Columbia are underlain by rocks of the Yukon-Tanana Terrane (YTT) and the Big Salmon Complex (cf. Mortensen, 1992; Gordey and Makepeace, 1999). Rocks formerly referred to as Dorsey Terrane are now considered to be a part of the YTT (Figs. 2, 32; (Mortensen, 1992; Stevens, 1992, 1994; Stevens and Erdmer, 1993; Stevens and Harms, 1995; Creaser et al., 1995; Gordey, 1995; Stevens et al., 1996; Mihalynuk et al., 1998). The Big Salmon Complex is the subject of ongoing study by Nelson (1997, 1999). Strata of the Rapid River tectonite (Fig. 2) in northern British Columbia may also be correlative with the YTT (Nelson, 1997).

Several VMS prospects occur in the Teslin-Rancheria area and across the border in northern British Columbia. The Mor, Cabin Creek, Caribou Lake, Bar (Eng), Iron Creek (Big Top) and Bar (Dan, Swift River) prospects occur in the Yukon; brief descriptions are below. In British Columbia, the Arsenault stratabound chalcopyrite-pyrite-pyrrhotite showing and metarhyolite of probable early Mississippian age, accompanied by metamorphosed iron formation, occurs within the Big Salmon Complex (Nelson, 1997). Bands of early Mississippian pyritic quartz-sericite schist, interpreted to be metamorphosed rhyolitic tuffs, occur at several localities in the central Jennings River area (Nelson et al., 1998; Nelson, 1997; 1999).

TESLIN-RANCHERIA AREA

Mor

The Mor property is located near the Alaska Highway in the Morley River area (Fig. 32; NTS 105C/1). The property occurs about 12 km northeast of occurrence 105C 059 (Yukon MINFILE, 2001, 60°00'53"N, 132°12'03"W). The claims were staked to cover stream silt geochemical anomalies and a base and precious metal-rich showing. The property is underlain by metamorphosed sedimentary and volcanic rocks of the Nasina Assemblage of the Yukon-Tanana Terrane (Gordey and Makepeace, 1999), including at least a 900-m strike length of mineralized felsic metavolcanic rocks (Fairfield Minerals Ltd., 2001). Geochemical results have outlined a 2000 x 100 to 200 m area with anomalous copper, lead, zinc and silver values. Significant mineralization has been found in two areas: the Discovery showing and an unnamed showing about 450 m to the east. Grab samples of mineralized quartz-sericite schist from the Discovery showing returned values of up to 8910 ppb Au, 82.2 ppm Ag, 10 500 ppm Cu, 5081 ppm Pb and 5515 ppm Zn. Samples of disseminated and semi-massive pyrite-chalcopyrite mineralization from trenches returned values of up to 1250 ppb Au, 42 g/t Ag, 0.13% Cu, 0.43% Pb and 0.40% Zn. Samples from the unnamed showing returned up to 570 ppb Au, 9.2 ppm Ag, 411 ppm Cu, 1050 ppm Pb, 714 ppm Zn and 8800 ppm Ba. Ground geophysical surveys identified several discrete very low frequency – electromagnetic (VLF-EM) conductors with associated magnetic response that are locally coincident with anomalous multi-element soil geochemical trends.

Caribou Creek

The Caribou Creek property is located about 180 km east of Whitehorse in the Wolf Lake area (Fig. 32; Yukon MINFILE, 2001, 105C 062; 60°15'44"N, 132°03'08"W; NTS 105C/08). Strata underlying this area were correlated with the Nasina Assemblage by Gordey and Makepeace (1999). The property is underlain by a bimodal metavolcanic sequence with gossanous horizons (Fairfield Minerals Ltd., 2001). Soil sampling has identified several areas with anomalous values of up to 2675 ppm Cu, 2047 ppm Pb, 1346 ppm Zn, 8.5 ppm Ag and 2320 ppb Au. Trenching exposed locally pyritic quartz-sericite schist that returned moderately anomalous lead, silver and gold values. An induced polarization (IP) survey identified several zones of moderate chargeability within an area of anomalous soil geochemistry. Airborne electromagnetic (EM) and magnetic surveys identified several weak EM anomalies and magnetic trends parallel to stratigraphy.

Cabin Lake

The Cabin Lake property is located east of Whitehorse in the Cabin Lake area (Fig. 32; Yukon MINFILE, 2001, 105B 144; 60°06'07"N, 131°47'32"W; NTS 105B/4). The property is underlain by stratigraphy that has been correlated with the Nasina Assemblage (Gordey and Makepeace, 1999), including a bimodal metavolcanic sequence with gossanous horizons (Fairfield Minerals Ltd., 2001). Disseminated pyrite-chalcopyrite mineralization occurs in quartz-mica schist (Burke, 1999). Soil sampling identified an 800 x 4000 m, >250 ppm Cu anomaly with peak values up to 3000 ppm Cu, and lesser coincident anomalous silver, lead and zinc values (Burke, 1998).

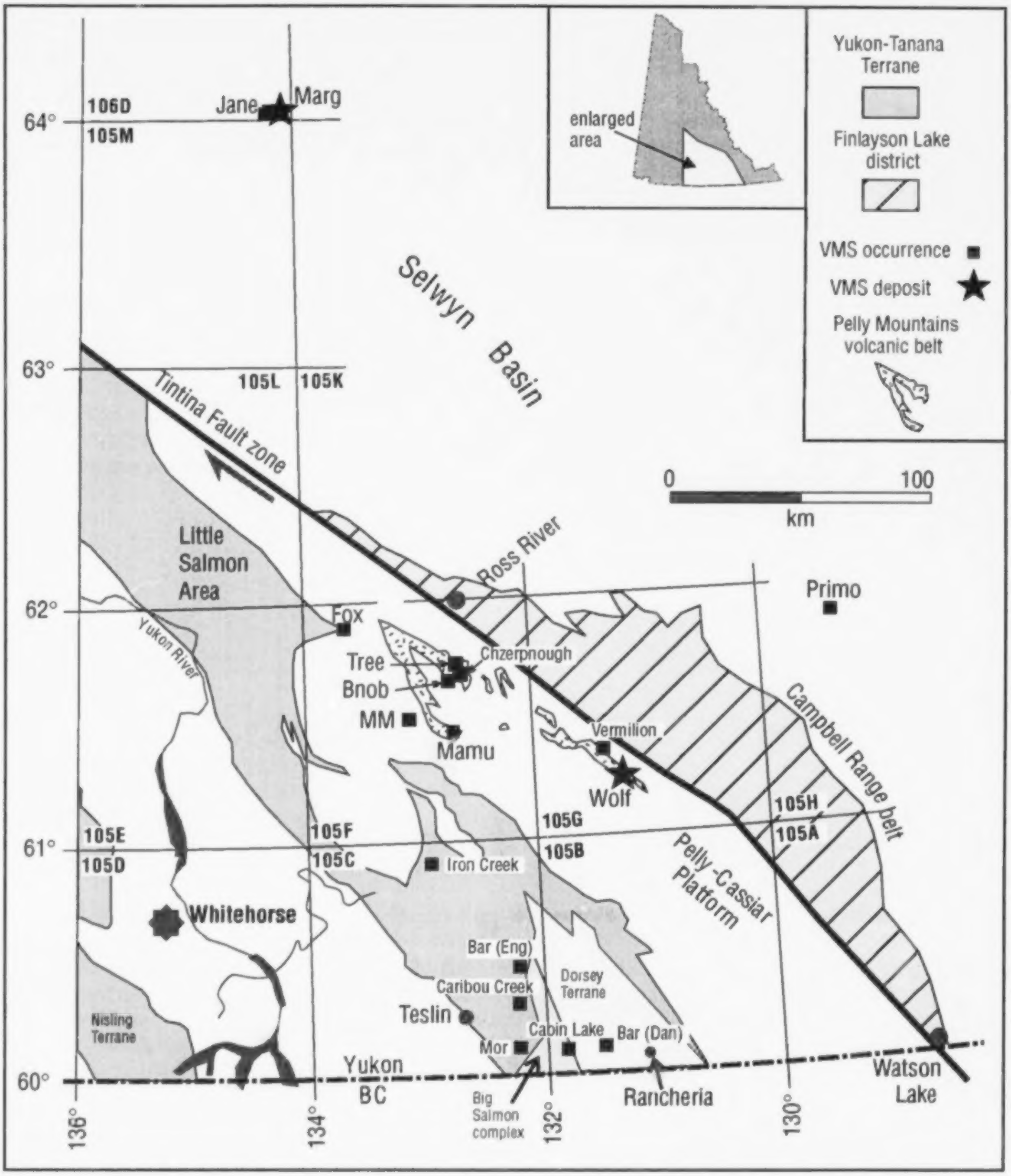

Yukon-Tanana Terrane
Finlayson Lake district
VMS occurrence
VMS deposit
Pelly Mountains volcanic belt
enlarged area
Selwyn Basin
Tintina Fault zone
0
100
km
Jane
Marg
106D
105M
105L
105K
Little Salmon Area
Yukon River
Ross River
Primo
Fox
Tree
Bnob
MM
Mamu
Chzerpnough
Vermilion
Wolf
Campbell Range belt
105H
105A
105G
105B
105E
105D
105F
105C
Iron Creek
Whitehorse
Pelly-Cassiar Platform
Bar (Eng)
Dorsey Terrane
Caribou Creek
Teslin
Cabin Lake
Bar (Dan)
Mor
Nisling Terrane
Yukon
BC
Big Salmon complex
Rancheria
Watson Lake
64°
63°
62°
61°
60°
136°
134°
132°
130°

Figure 32. Present location of the Pelly-Cassiar Platform and Selwyn Basin. The location of deposits and showings in the Teslin-Rancheria area, the Pelly Mountains volcanic belt (PMVB) and the Selwyn Basin are shown.

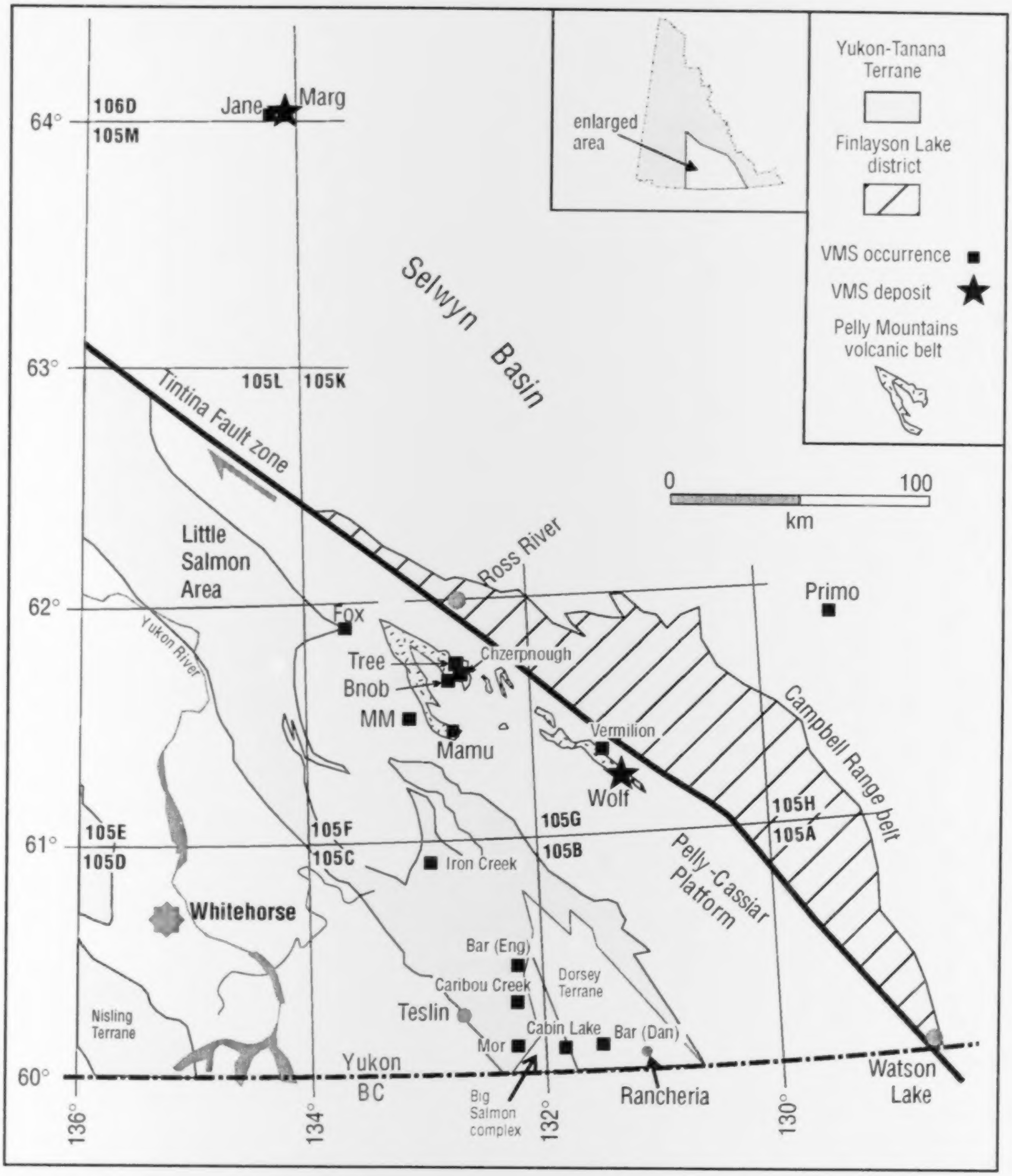

Yukon-Tanana Terrane
Finlayson Lake district
VMS occurrence
VMS deposit
Pelly Mountains volcanic belt
enlarged area
0
100
km
Selwyn Basin
Tintina Fault zone
Little Salmon Area
Ross River
Primo
Fox
Tree
Bnob
Chzerpnough
MM
Mamu
Vermilion
Wolf
Campbell Range belt
Pelly -Cassiar Platform
Jane
Marg
106D
105M
105L
105K
105E
105D
105F
105C
105G
105B
105H
105A
Yukon River
Iron Creek
Whitehorse
Bar (Eng)
Caribou Creek
Dorsey Terrane
Teslin
Nisling Terrane
Cabin Lake
Bar (Dan)
Mor
Yukon
BC
Big Salmon complex
Rancheria
Watson Lake
64°
63°
62°
61°
60°
136°
134°
132°
130°

Figure 32. Present location of the Pelly-Cassiar Platform and Selwyn Basin. The location of deposits and showings in the Teslin-Rancheria area, the Pelly Mountains volcanic belt (PMVB) and the Selwyn Basin are shown.

Bar (Eng)

The Bar (Eng) property (Fig. 32; Yukon MINFILE, 2001, 105C 003; 60°30'17"N, 132°14'20"W) is located near the Wolf River at the southern end of NTS map 105C/9. This area is underlain by medium to dark green to purple-grey, locally amygdaloidal or vesicular intermediate to mafic volcanic flows, flow breccias, volcanic fragmentals and tuffs (Gordey and Makepeace, 1999). Massive, bedded barite at least 15 m thick occurs at the base of an early Mississippian pyritic chert unit. Thin lamellae and veinlets of pyrite and minor lenses of galena-sphalerite-tetrahedrite are abundant in the lower part of the barite (Yukon MINFILE, 2001). The barite is underlain by a pyritic zone up to 24 m thick. Stratigraphy beneath the pyritic zone is cross-cut by 'veins' of massive pyrite and barite-galena up to 4 m thick (ibid.).

Iron Creek (Big Top)

The Big Top property (Fig. 32; Yukon MINFILE, 2001, 105C 021; 60°51'51"N, 133°18'35"W; NTS 105C/14) is located at the south end of Quiet Lake in an area of the YTT underlain by Nasina Assemblage rocks that may locally include significant amounts of Klondike Schist (Gordey and Makepeace, 1999). The property is, in part, underlain by interlayered carbonaceous argillite and pyritic metavolcanic rocks. Eleven outcrop samples were examined from the property (Appendix VI-3: specimens JH97-64a, 123, 249, 250, 256, 258, 264, 97R254, 97R261). Most of the samples appear to be metadacite composed mainly of quartz and probable albitic alkali feldspar with lesser amounts of carbonate, biotite, sericite, chlorite, sphene and sulphide (Leitch, 1998, Appendix VI-3). Multi-element geochemical anomalies with up to 8.9 ppm Ag, 351 ppm Cu, 669 ppm Pb and 3361 ppm Zn and coincident electromagnetic and magnetic anomalies occur on the property (Burke, 1998). Disseminated sulphides and quartz veins occur in several discordant silicified, sericitized and chloritized zones.

Bar (Dan, Swift River)

The Bar (Dan, Swift River) property (Fig. 32; Yukon MINFILE, 2001, 105B 027; 60°10'22"N, 131°07'46"W; NTS 105B/3) is located midway between Teslin and Watson Lake. This area is underlain by Nasina Assemblage and Earn Group rocks near the margin of the mid-Cretaceous Cassiar batholith (Gordey and Makepeace, 1999). Early exploration on the property classified the mineralization as skarn based on calcsilicate host rocks. The present operator has reinterpreted the geology and suggests the property contains a series of exhalative deposits with regional and contact metamorphic overprints (Burke, 1999). Detailed mapping shows that the property is, in part, underlain by interlayered tuffaceous metavolcanic rocks and calcareous metasedimentary rocks (ibid.). An examination of a sample from the 'Discovery showing' on the Dan property (Appendix VI-3: specimen JH97-53) shows it is most likely calcsilicate hornfels. Certain aspects of the rock such as the presence of rutile, mafic minerals and plagioclase suggest that it could have been derived from an intermediate-mafic volcanic rock. An examination of a sample from the 'lost outcrop' (Appendix VI-3: specimen JH97-54) shows that it is primarily calcsilicate with many similarities to specimen JH97-53. An examination of a sample from the 'Lucy showing' (Appendix VI-3: specimen JH97-55) shows it also has similar mineralogy to the previous samples; the presence of sphene, amphibole, epidote and chlorite suggest a mafic protolith (Leitch, 1998, Appendix VI-3).

Mineralization on the property includes massive to semi-massive pyrrhotite, magnetite and sphalerite in several showings within calcsilicate and metavolcanic rocks (Burke, 1998). Results from drilling at the Dan showing include 14.57% Zn over 1.2 m and 6.55% Zn over 1.88 m (ibid.).

GLENLYON AREA

A belt of metasedimentary, metavolcanic and metaplutonic rocks, at least 20 km long, in the Glenlyon map area (NTS 105L) correlates with rocks of the Yukon-Tanana Terrane (cf. Colpron, 1999a; Colpron and Reinecke, 2000). Restoration of 425 km of dextral movement along the Tintina Fault places this belt of rocks south of the Finlayson Lake VMS district. Massive sulphide mineralization and chert horizons, likely volcanic-associated, have been discovered recently in the Glenlyon area (Colpron, 1999b; Colpron and Reinecke, 2000) and are described briefly below.

Colpron (1999b) describes pyrite-chalcopyrite mineralization near Little Salmon Lake. The mineralization is exposed in a roadcut on the north side of the Campbell Highway, about 12 km west of Drury Creek (Fig. 32; UTM zone 8, 520416E, 6895423N; NTS 105L/2). Sulphide mineralization occurs in two magnetite iron formation horizons 10 to 15 cm and about 50 cm thick hosted by a sequence of altered felsic metavolcanic rocks. A sample of the 10- to 15-cm-thick horizon returned values of 606 ppm Cu, 30 ppm Pb, 76 ppm Zn, 0.8 ppm Ag and 10 ppb Au (ibid.). A sample of the 50-cm-thick horizon returned values of 573 ppm Cu, 20 ppm Pb, 62 ppm Zn, 1.4 ppm Ag and <5 ppb Au (ibid.).

Manganiferous chert horizons occur within felsic metavolcanic rocks in the above belt (Colpron and Reinecke, 2000). The chert horizons contain up to 5% piedmontite (Mn-epidote) and are probably of exhalative origin (ibid.).

NORTH AMERICAN MIOGEOCLINE

The Yukon-Tanana Terrane (YTT) has been described by several authors (cf. Wheeler et al., 1991; Mortensen, 1992a) as a pericratonic terrane, likely a rifted-away portion of North America. Thus, it is possible that North American miogeoclinal strata may correlate with those of the YTT.

Within the Yukon, the North American miogeocline (NAM) is made up, in part, by the Selwyn Basin and the Pelly-Cassiar Platform (PCP; Figs. 1, 2; cf. Gordey and Makepeace, 1999). These geographic elements contain Devonian-Mississippian felsic to intermediate metavolcanic rocks that host VMS deposits and are in part coeval with those in the Finlayson Lake area of the YTT. The Selwyn Basin hosts the zinc-lead-copper Marg deposit and the PCP is host to the Wolf and MM zinc-lead-silver deposits and several VMS prospects (Fig. 32). The following sections describe these deposits and their host strata plus other prospective areas underlain by miogeoclinal rocks.

HISTORY AND GEOLOGY OF THE NORTH AMERICAN MIOGEOCLINE

A miogeoclinal sequence accumulated along the western margin of North America from approximately mid-Proterozoic to mid-Jurassic (Gordey and Anderson, 1993). Within the Yukon this sequence encompasses 1) Late Proterozoic to mid-Devonian strata made up of the proximal Ogilvie-Mackenzie Platform that passes laterally westward into deeper water rocks of the Selwyn Basin (Murphy, 1997c). In the Silurian and Devonian, Selwyn Basin passed westward into shallow-water carbonate and clastic rocks forming the Pelly-Cassiar Platform (PCP; Tempelman-Kluit, 1977a,b); 2) mid-Devonian to Mississippian strata that consist largely of basinal clastic rocks and chert (cf. Murphy, 1997c). During this time local explosive volcanism, especially in the PCP, produced thick tuffs and flows that intertongue with the surrounding black shale; and 3) mid-Mississippian to mid-Jurassic strata made up largely of marine shelf clastic and carbonate rocks (Gordey and Anderson, 1993; Murphy, 1997c). Tertiary strike-slip motion on the Tintina Fault separated the PCP from the bulk of the Sewlyn Basin (Figs. 1,2) and it now lies immediately west of the Finlayson Lake area of the YTT (cf. Roddick, 1967; Tempelman-Kluit, 1976; Mortensen, 1983; Gabrielse, 1991).

Locally, the mid-Devonian to Mississippian strata contain VMS base-metal mineralization (cf. Turner and Abbott, 1990; Morin, 1977; Holbeck and Wilson, 1998; Gibson et al., 1999) coeval with that in the YTT. The VMS occurrences, located in Figure 32, are described in the following sections; those in the PCP are described first, followed by those in the Selwyn Basin.

PELLY-CASSIAR PLATFORM

Within the Pelly-Cassiar Platform (PCP), Devono-Mississippian volcanic rocks form an arcuate belt about 80 km long and up to 25 km wide that is known informally as the Pelly Mountains volcanic belt (PMVB; Fig. 32). The belt was mapped at reconnaissance scale by the Geological Survey of Canada (Wheeler et al., 1960a,b; Tempelman-Kluit 1977a,b; Gordey, 1978, 1979), with more detailed local mapping by Gordey (1977), Chronic (1979), Mortensen (1979) and Hunt (1998c - as part of this study).

GEOLOGY

The present deformed thickness of volcanic rocks within the PMVB is variable, ranging from less than 100 m to as much as 1700 m (Gordey, 1977, 1981; Mortensen, 1979, 1981). As in any volcanic pile, individual lithologies vary in thickness and lateral extent due to irregular paleodepositional surfaces, proximity to volcanic vents and dynamic to catastrophic local tectonics. Consequently, correlation of individual rocks units between areas is difficult.

The southeast end of the volcanic belt generally forms a moderately south-dipping homoclinal succession that probably unconformably overlies, and is over-thrust by, cliff-forming carbonate and limey siltstone/shale (Gordey and Tempelman-Kluit, 1976; Gordey, 1977). In the vicinity of the Wolf deposit (Fig. 32), the volcanic succession is made up primarily of felsic volcaniclastic material with lesser felsic sills, dykes or flows and minor intermediate sills, dykes or flows (Fig. 33a; for detailed information and stratigraphic sections see Hunt, 1999a). The base of the succession consists of dominantly brown-pink lapilli tuff interbedded with argillite and lesser trachyte sills or dykes. The middle of the succession is made up primarily of heterolithic lapilli tuff containing argillite clasts (Fig. 33b), maroon matrix tuff/breccia with green fragments from 1 to 60 cm across (Fig. 33c) and trachyte flows, sills or dykes (Fig. 33d). The upper part of the succession consists of chlorite-altered volcaniclastic rocks and intermediate dykes and flows. The Wolf deposit occurs in the middle portion of the volcanic succession proximal to a syenite intrusion (Holbek and Wilson, 1998; Gibson et al., 1999; Hunt, 1999a).

Near the centre of the volcanic belt, the felsic volcaniclastic component decreases. The number of sills, flows and dykes becomes more numerous, and the amount of intermediate volcanic material increases (for detailed information and stratigraphic sections see Hunt, 1999a).

At the northwest end of the PMVB the volcanic succession lies on, and is locally interbedded with, black shale of the Earn Group (cf. Gordey, 1979; Mortensen, 1981). Thrust over the volcanic rocks, at least locally, are Cambrian to Ordovician carbonates of the Kechika Group (cf. Gordey and Makepeace, 1999). In this part of the belt, volcanic units of intermediate composition constitute the bulk of the volcanic succession; however, felsic volcanic rocks similar to those at the southeastern end of the belt occur in the middle of the volcanic sequence. Within these Late Devonian to early Mississippian (Mortensen, 1981 and pers. comm., 1997) felsic volcanic rocks, Morin (1977) and Mortensen (1979) describe several submarine volcanic complexes where extensive volcaniclastic strata are interbedded with flows and tuffaceous chert, and intruded by felsic domes and stocks. The felsic intrusions are syenitic in composition and were considered by Tempelman-Kluit (1976), Morin (1977) and Mortensen (1979, 1981) to be the subvolcanic equivalent of some of the felsic tuffs and flows. Locally, the felsic tuffs contain pyrite and are immediately overlain by massive sulphide lenses, for example at the MM deposit (Morin, 1977; Mortensen, 1979, 1981; Mortensen and Godwin, 1982).

Metamorphism and alteration

Most of the volcanic strata within the belt are lower greenschist facies regional metamorphic grade (Gordey, 1981; Tempelman-Kluit et al., 1976) with the exception of the northwest end of the belt, around the MM occurrence, where the strata reach lower amphibolite facies (Mortensen and Godwin, 1982). The volcanic rocks are characterized throughout the belt by pervasive clay and carbonate alteration and fine-grained disseminated pyrite (Morin, 1977; Mortensen, 1979; Holbek and Wilson, 1998; Gibson et al., 1999; Hunt, 1999a)

Structure

Rocks of the PCP, including the PMVB, are internally repeated by folds and northeast-directed thrust faults, which involve strata as young as Upper Triassic (Tempelman-Kluit, 1977a). The northwestern end of the volcanic belt has been affected by three phases of deformation (Mortensen, 1981). All three phases are seen together only near the MM occurrence where the host rocks are intensely folded; in other parts of the belt the folding is less intense. The first two phases are coaxial with a general northwesterly trend; the third phase produced northeasterly trending regional warps (Mortensen, 1979, 1981). Mortensen (1981) suggested the first two phases of deformation reflect nappe development during thrusting, and the unrelated third phase is possibly the result of intrusion of Cretaceous granitic batholiths to the southwest, or initial wrenching on the Tintina Fault. The southeast end of the belt is less deformed than the northwest end and folds are rarely seen.

GEOCHEMISTRY

Available geochemical information (Mortensen, 1981; Gordey, 1977; Holbek and Wilson, 1998; this study) indicates the felsic volcanic rocks within the PMVB are metaluminous calc-alkalic trachytes to rhyolites. In general the felsic volcanic rocks are enriched in potassium and depleted in sodium (Mortensen, 1979; Mortensen and Godwin, 1982; MacRobbie, 1991; Gibson et al., 1999). The high potassium content of the felsic volcanic rocks lowers the viscosity of the magma and features such as ropey texture and pillows, more commonly associated with flood basalts, occur locally in outcrop (Gibson et al., 1999; this study). Syenite at the Wolf property is chemically distinct with potassium and sodium contents that are approximately equal (in most other rocks on the Wolf property the ratio is 8 or 9:1; Gibson et al., 1999).

Trace element data (Morin, 1977; Gordey, 1977; Chronic, 1979; Mortensen, 1981) indicate the trachytic rocks resemble peralkaline volcanic rocks generated in extensional environments (Mortensen and Godwin, 1982 and Mortensen, 1982). The platformal setting on a continental margin, the high-potassium geochemistry of the volcanic rocks, and the presence of bedded barite and volcanogenic massive sulphide deposits indicate that the PMVB was likely deposited in a continental rift-type environment (ibid.). Supporting evidence for this conclusion is provided by the documentation of contemporaneous extension within the Selwyn Basin, and by the presence of an unconformity beneath the volcanic sequence, which suggests at least local uplift (Blusson, 1976; Tempelman-Kluit and Blusson, 1977; Gordey, 1978 and 1979).

MAIN MINERAL OCCURRENCES/ DEPOSITS

Wolf

The Wolf deposit (Fig. 32, 33a; Yukon MINFILE, 2001, 105G 008; 61°20'25"N; 131°29'32"W; NTS 105G/6) is located at the south end of the PMVB. Zinc-lead-silver mineralization is hosted within a sequence of tuffs and trachyte flows, sills and/or dykes proximal to a thick syenite sill (Gibson et al., 1999).

Property geology and mineralization

The Wolf property was mapped in detail by MacRobbie (1991). A description of the deposit stratigraphy can be found in Holbek and Wilson (1998) and Gibson et al. (1999). The following is summarized mainly from these sources, but takes advantage of observations made during this study.

The Wolf property has two main areas of mineralization: the Wolf deposit, and the East Slope zone (Fig. 34a). The Wolf deposit occurs as a thickened part (average 12 m) of a laterally extensive massive sulphide layer (Gibson et al. 1999). The deposit dips to the south at approximately 45° and has a strike length of 125 m, a down-dip length of 400 m, and an inferred resource of 4.1 million tonnes with grades of 6.2% Zn, 1.8% Pb and 84 g/t Ag (ibid.). The deposit is hosted by a succession of altered lapilli and ash tuffs, pyritic ash tuff, and mudstone that occurs below a sequence of massive to porphyritic trachyte flows. Generally the massive sulphide mineralization is separated from the overlying flows by a thin, laterally extensive, pyritic lapilli tuff unit and/or a thin layer of argillite. The pyritic lapilli tuff unit is distinctive. It is strongly sericite-altered and contains 10 to 20% dominantly massive pyrite fragments 3 to 15 mm across. The massive sulphide mineralization is underlain by laterally extensive, 3- to 5-m-thick, foliated, banded, fine-grained barite-carbonate exhalite with disseminated to semi-massive sulphides. The south side of the Wolf horizon has been down-dropped about 65 m (Fig. 34b).

The second area of mineralization is the East Slope zone which occurs 1200 m to the east of the Wolf deposit (Fig. 34a) proximal to a sill-like (A.M. Gibson, pers comm., 1999) syenite intrusion. Mineralization, hosted by a package of ash tuffs and volcaniclastic rocks, is cut by quartz-phyric trachyte dykes and/or sills, similar to those that underlie the Wolf deposit. The trachyte flows and/or sills and adjacent rocks contain iron-carbonate nodules (Fig. 33e), which may be a form of peperite caused by injection of magma into wet tuffs and sediments.

Mineralization in the East Slope zone consists of five narrow massive sulphide horizons within an approximately 80-m-thick section of disseminated lead-zinc mineralization (Gibson et al., 1999). The lowermost horizon is a bedded barite-carbonate-pyrite exhalite up to 18 m thick with minor disseminated sphalerite and galena. Gibson et al. (1999) correlate this horizon with barite-carbonate exhalite that underlies massive sulphide mineralization in the Wolf deposit and massive barite-galena mineralization in the area northwest of Mount Vermilion. Silicified brecciated trachyte with 15% disseminated to interstitial pyrite and up to 2% combined disseminated sphalerite and galena occurs below this horizon in the East Slope zone (Fig. 33f; ibid.). Gibson et al. (1999) suggest that the brecciated trachyte may be part of a flow-dome complex.

In general, mineralization at the Wolf deposit occurs as stratiform pyrite, carbonate, sphalerite, galena and barite, with rare specular hematite and chalcopyrite (Gibson et al., 1999). In the Wolf horizon, the massive sulphide mineralization consists mainly of fine-grained pyrite with bands of amber sphalerite and fine-grained steel grey galena (Fig. 33g; ibid.). Within this horizon the sulphides generally grade from banded galena-pyrite to variably textured medium-grained sphalerite-pyrite. Locally, medium-grained botryoidal sphalerite and galena occur within a gangue of buff-coloured iron-magnesium carbonate, and more rarely, barite. Chalcopyrite is rare but occurs locally in quartz-carbonate stringers below the Wolf horizon.

Exploration techniques

Geochemistry: Soil sampling results have defined a large >100 ppm Pb anomaly (see Fig. 2 in Holbek and Wilson, 1998) with coincident >300 ppm Zn and >0.6 ppm Ag and spotty >3500 ppm Ba on the Wolf property (Carne, 1990; MacRobbie, 1991; Holbek and Wilson, 1999). Pearl creek, which drains the Wolf deposit, contains elevated levels of lead and zinc (Hunt, 1999b) and the stream bed is coated by a white precipitate composed of amorphous silica (Robitaille and Thompson, 1999 in Appendix VI-4).

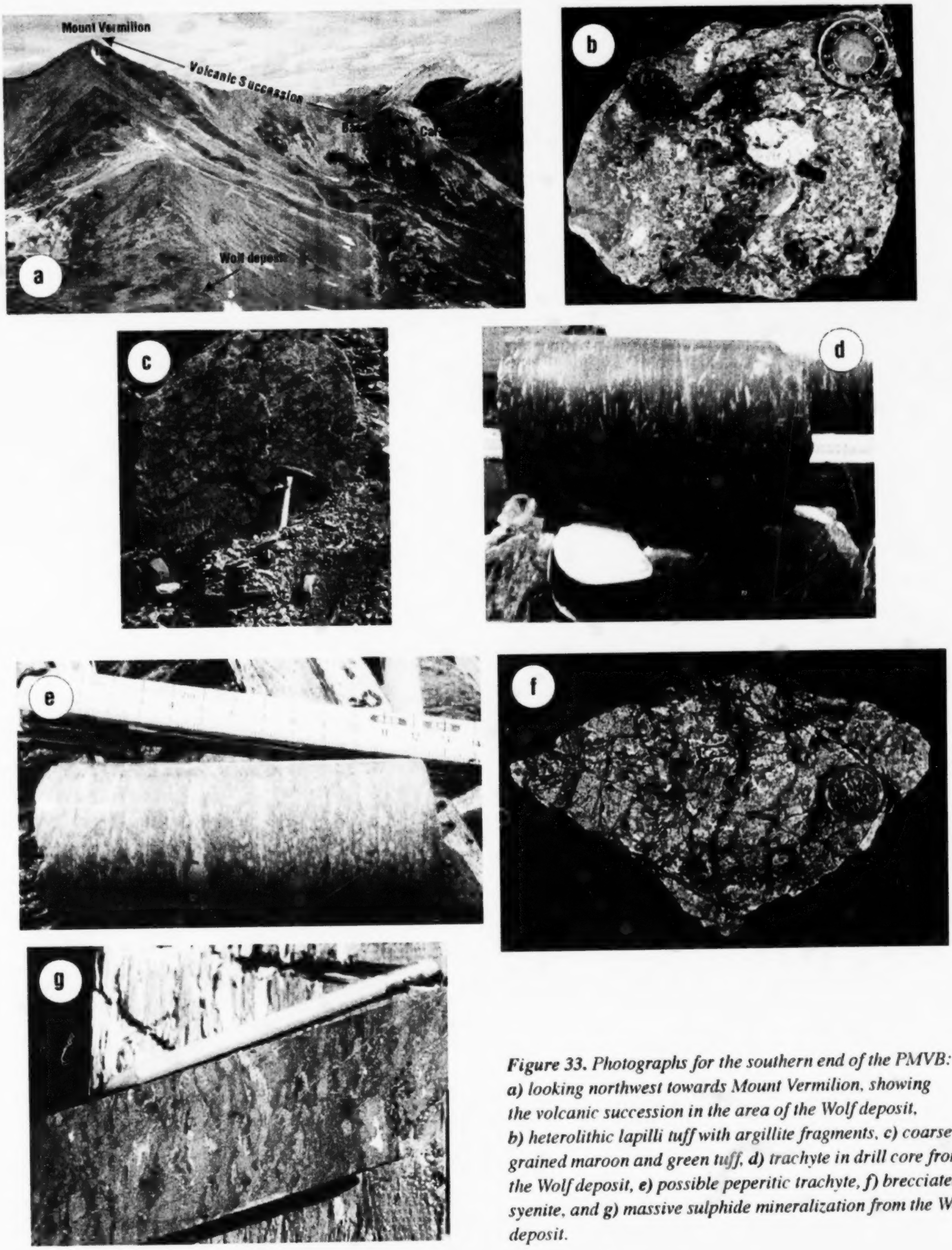

a
Mount Vermilion
Volcanic Succession
Wolf deposit
b
c
d
e
f
g

Figure 33. Photographs for the southern end of the PMVB: a) looking northwest towards Mount Vermilion, showing the volcanic succession in the area of the Wolf deposit, b) heterolithic lapilli tuff with argillite fragments, c) coarse-grained maroon and green tuff, d) trachyte in drill core from the Wolf deposit, e) possible peperitic trachyte, f) brecciated syenite, and g) massive sulphide mineralization from the Wolf deposit.

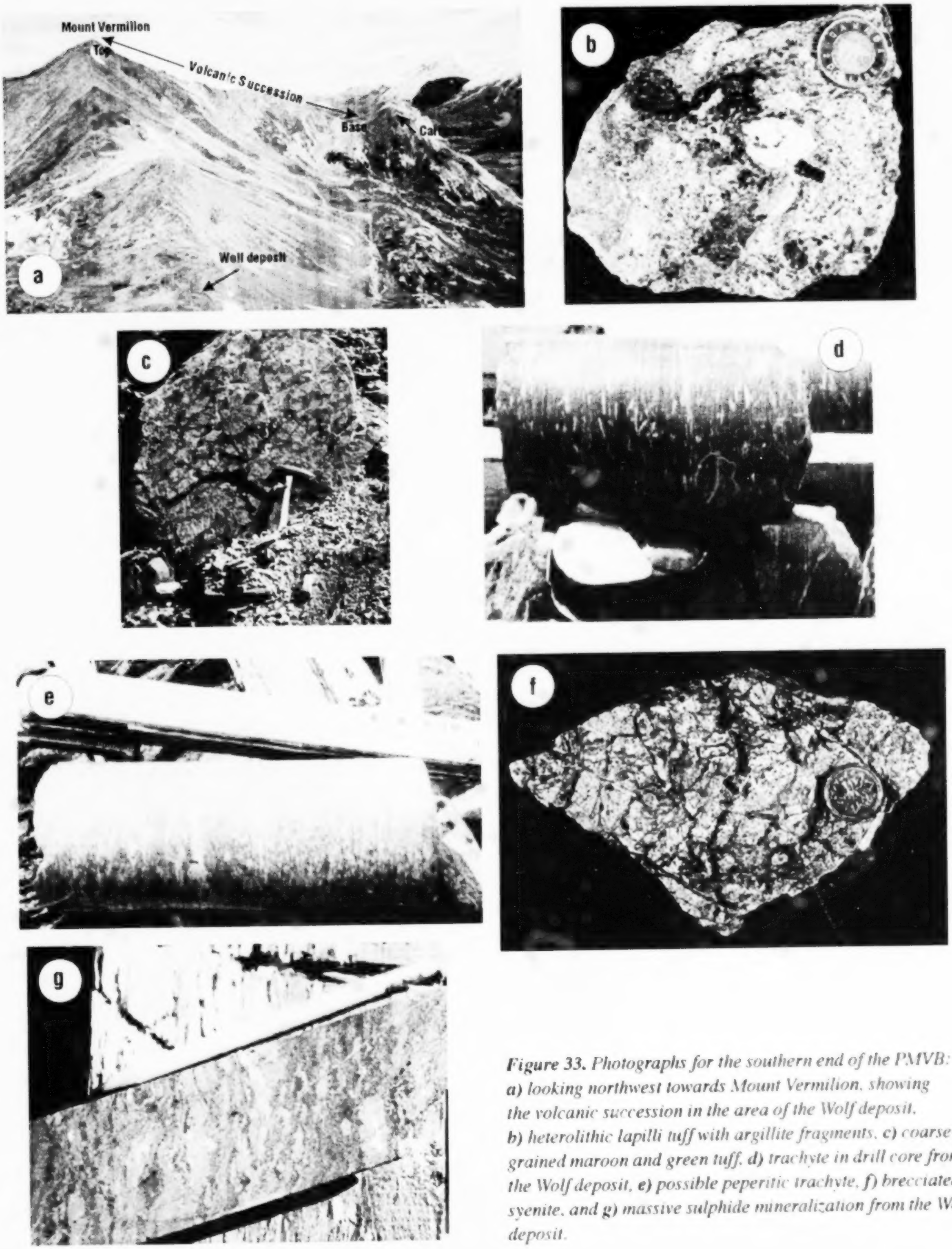

Mount Vermilion
Top
Volcanic Succession
Base
Ca
Wolf deposit
a
b
c
d
e
f
g

***Figure 33.** Photographs for the southern end of the PMVB: **a)** looking northwest towards Mount Vermilion, showing the volcanic succession in the area of the Wolf deposit, **b)** heterolithic lapilli tuff with argillite fragments, **c)** coarse-grained maroon and green tuff, **d)** trachyte in drill core from the Wolf deposit, **e)** possible peperitic trachyte, **f)** brecciated syenite, and **g)** massive sulphide mineralization from the Wolf deposit.*

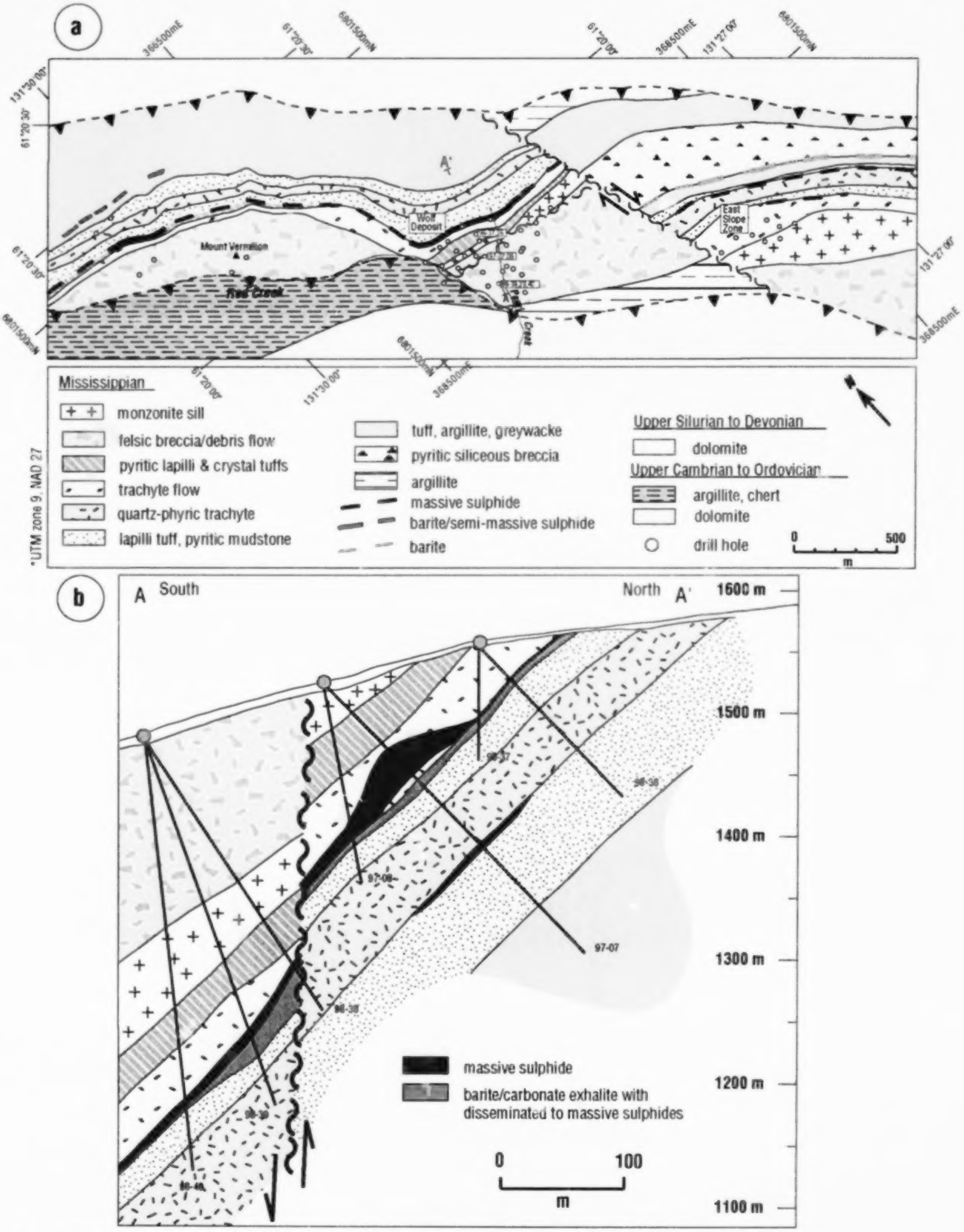

a
366500mE
61°20'30"
6801500mN
61°20'00"
368500mE
131°27'00"
131°30'00"
A'
Wolf Deposit
East Slope Zone
Mount Vermilion
Red Creek
Creek
Mississippian
monzonite sill
felsic breccia/debris flow
pyritic lapilli & crystal tuffs
trachyte flow
quartz-phyric trachyte
lapilli tuff, pyritic mudstone
tuff, argillite, greywacke
pyritic siliceous breccia
argillite
massive sulphide
barite/semi-massive sulphide
barite
Upper Silurian to Devonian
dolomite
Upper Cambrian to Ordovician
argillite, chert
dolomite
drill hole
0
500
m
°UTM zone 9, NAD 27
b
A South
North A'
1600 m
1500 m
1400 m
1300 m
1200 m
1100 m
97-07
97-08
98-38
98-40
massive sulphide
barite/carbonate exhalite with disseminated to massive sulphides
0
100
m

Figure 34. Wolf deposit: a) geological plan, and b) drill section 5210E (figures modified from Gibson et al., 1999).

Geophysics: Ground geophysics in the immediate area of the Wolf deposit outlined several conductive features, some relating to conductive mudstone, others relating to major structures, and others (see Fig. 2 in Holbek and Wilson, 1998) interpreted to be related to base metal mineralization (Holroyd, 1993; Holbek and Wilson, 1998). The felsic volcanic rocks exhibit a slightly elevated magnetic susceptibility, but the most prominent magnetic features are related to the syenitic intrusive (Holroyd, 1993).

A helicopter-borne electromagnetic (EM) magnetometer and very low frequency (VLF-)EM survey was completed over the entire belt of rocks containing the Wolf deposit (Lo and Gibson, 1999). Overall, the geophysics suggests a linear belt of mixed sedimentary and intermediate to felsic volcanic rocks along with discontinuous and thin mafic flows. In general, the areas of low magnetic response are interpreted to be underlain by sedimentary rocks and those with higher magnetic response are interpreted to be underlain by intermediate to felsic volcanic rocks (ibid.). The linear magnetic bodies are interpreted as mafic volcanic rocks but could be syenite sills. The airborne geophysical survey resulted in the identification of 46 areas that may contain mineralization or alteration.

MM

The MM prospect (Fig. 32; Yukon MINFILE, 2001, 105F 012; 61°25'N, 132°40'W; NTS 105F/7) is located on the west side of the PMVB. Zinc-lead-silver ± copper mineralization occurs within a rusty-weathering volcanic-dominated sequence (Fig. 35a,b) about 200 m thick that is over- and underlain by carbonaceous pelitic sediments (Morin, 1977; Mortensen and Godwin, 1982). This area is highly deformed and metamorphosed; much of the stratigraphic sequence is isoclinally folded.

Mineralization on the MM property is made up of several sulphide lenses along a roughly east-west trend. On the east side of the trend, mineralization consists of three separate mineralized lenses each about 100 m long and several tens of metres thick (Morin, 1977). The mineralization is hosted by a pyritic quartzite layer sandwiched between intermediate and felsic metavolcanic rocks. This volcanic sequence has been traced, through drilling, to the southwest where it passes laterally into a trachyte dome flanked by volcanic breccia (Mortensen and Godwin, 1982). On the west side of the trend mineralization occurs as narrow lenses in the middle and upper parts of the volcanic sequence. The largest lens in this area is about 2 m thick and lies above the trachyte dome.

Footwall strata are predominantly made up of quartz with varying amounts of chlorite, biotite and sericite schist, and quartzite. Probable protoliths include intermediate to mafic volcanic rocks (Appendix VI-3: specimens DDH 77-03-978', 1072'; DDH 96-01-876', 982'). A cherty horizon, that may be exhalite, is also present (Appendix VI-3: specimen DDH 96-01-982').

Hanging wall rocks are predominantly made up of quartz-sericite ± chlorite, biotite-chlorite ± quartz (locally garnetiferous) and quartz-chlorite ± actinolite schists and lesser quartzite. The immediate hanging wall to mineralization on the east side (Appendix VI-3: specimen DDH 73-02-206') is quartz-sericite schist that may have had a siliceous, clastic protolith. Hanging wall rocks immediately above mineralization on the west side (Appendix VI-3: specimens DDH 77-03-788'; DDH 96-01-600') are made up primarily of garnetiferous schist composed of variable amounts of biotite, chlorite, quartz and muscovite/sericite. These rocks may, at least in part, be strongly altered and metamorphosed intermediate to possibly mafic rocks. Elsewhere, hanging wall rocks consist of sericite-chlorite-quartz schist with lensoid clasts of cream-coloured porphyritic felsic metavolcanic rock, suggesting the protolith was at least in part felsic volcanic breccia (Morin, 1977).

Mineralization

The eastern mineralized lenses consist of sulphide-silicate gneiss, quartzite, massive sulphide and barite units (Morin, 1977). Massive pyrite alternates with barite in the upper portion of the mineralized zone and forms the topmost unit in which sulphides are concentrated. The mineralization (Appendix VI-3: specimens DDH 73-02-345'; DDH 74-02-840.5', 864.5';

Figure 35. *Photographs for the MM, Bnob (Ice), Chzerpnough (Fire) and Marg occurrences:* ***a)*** *and* ***b)*** *rusty-weathering felsic metavolcanic rocks on the MM property, c) rusty-weathering felsic metatuff on the Chzerpnough property, d) massive barite bed on the Bnob property, e) massive sulphide mineralization from the Marg deposit, f) and g) primary layering and colomorphic and framboidal textures preserved in sulphide mineralization from the Marg deposit (reflected light, fields of view = 0.7 mm each; Leitch, 1998).*

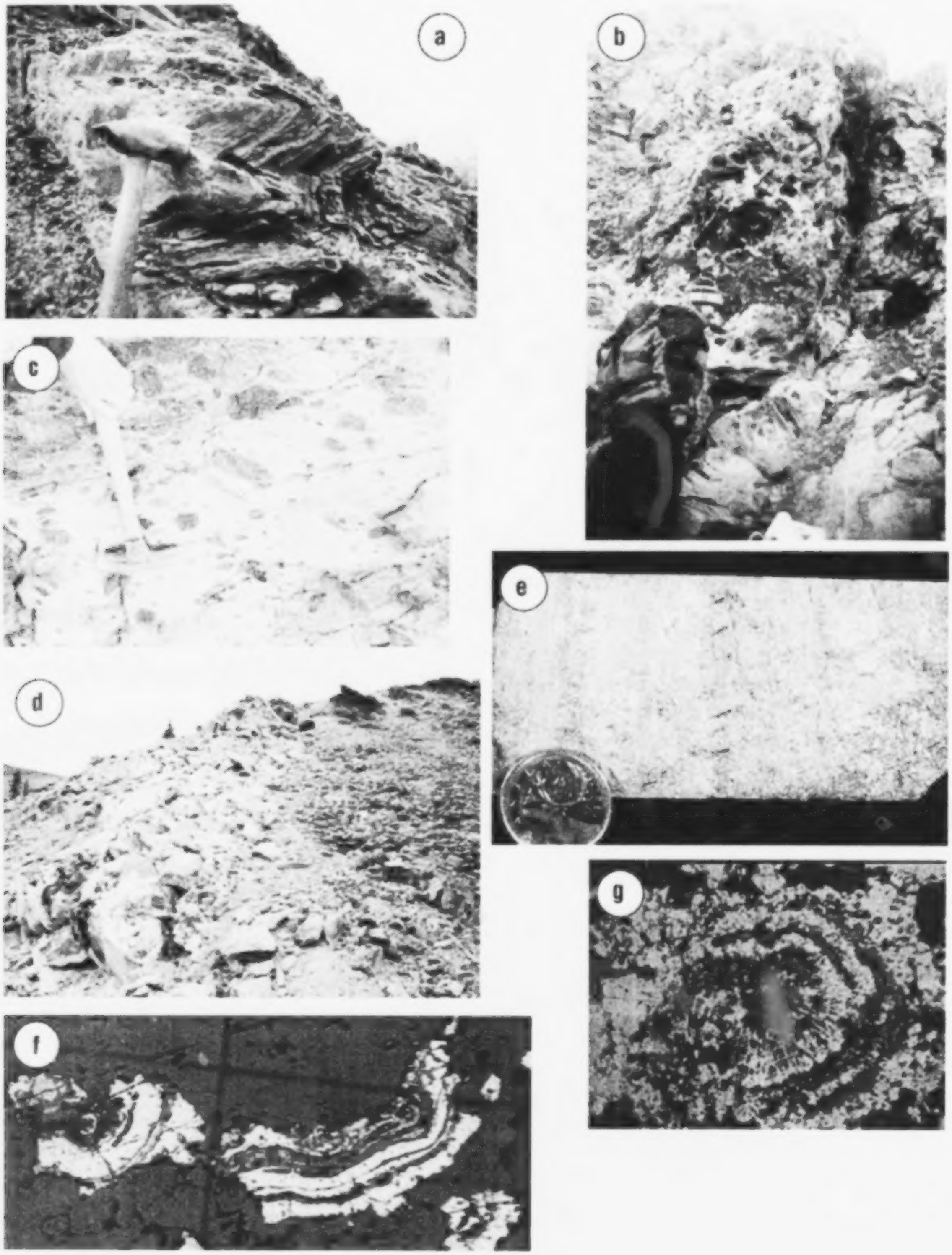


Figure 35. (caption on preceding page)

DDH 76-02-410', 423', 448'; DDH 76-07-644', 655', 726') consists mainly of massive to semi-massive pyritic sulphides with lesser sphalerite, galena and pyrrhotite and rare chalcopyrite and magnetite. The sphalerite is dominantly red-brown. Magnetite occurs locally as porphyroblasts. Locally, the sulphides occur as pyrite-pyrrhotite-sphalerite-barite-muscovite ± fluorite ± galena ± chalcopyrite stringers up to 1 cm thick in a fine-grained matrix of barite and sericite. Other associated minerals include quartz, carbonate, barite, biotite, sericite, chlorite, minor epidote and amphibole, and rare fluorite. No primary textures are preserved within the sulphides, silicates or carbonates. However, several samples (Appendix VI-3: specimens DDH 73-02-345'; DDH 74-02-840.5'; DDH 76-07-644', 726') contain relict quartz and feldspar phenocrysts and other features, which suggest an original igneous protolith has been replaced by sulphides and secondary silicates and carbonate (Leitch, 1998).

The western mineralization (Appendix VI-3: specimens DDH 77-01-933'; DDH 77-03-825', 830', 867.5'; DDH 96-01-682.5', 691', 722') varies from disseminated to laminated semi-massive to massive pyrite to sphalerite-rich sulphides with lesser pyrrhotite, galena and chalcopyrite. The sphalerite is dominantly red-brown. Laminated pyrite-rich and sphalerite-pyrrhotite-galena or sphalerite ± chalcopyrite-rich layers (Appendix VI-3: specimen DDH 77-03-825') may represent primary compositional layering. Pale pink garnets (Appendix VI-3: specimen DDH 96-01-682.5') could be manganese-rich and reflect an exhalative protolith (Leitch, 1998). Augen of fluorite up to 0.7 cm across are preserved locally within massive sulphide (Appendix VI-3: specimen DDH 77-03-830'). As in the eastern mineralization, primary textures are rare. Relict mafic and feldspar minerals, however, indicate some units may have an igneous protolith. Pyrite and pyrrhotite also occur throughout the host sequence as disseminations, blebs, bands, veinlets and porphyroblasts.

Disseminated, banded and massive sulphide base metal mineralization within the volcanic section decreases and becomes increasingly baritic eastward away from the east-side mineralization. Compared to the east side, samples of west-side mineralization have almost no barium, less pyrrhotite, more sphalerite and galena, carbonate is not ubiquitous and the sulphides are vaguely layered. No stringers were seen in samples from west-side mineralization collected during this study. However, Mortensen and Godwin (1982) reported 12 m of stringer-style mineralization within a massive trachyte dome beneath a sulphide lens. They suggest that this stringer mineralization represents part of the vent zone for the massive sulphide mineralization. The increase in barite to the east suggests that this may be an area of mineralization more distal from the vent. Mortensen and Godwin (1982) report that small, increasingly baritic and pyritic sulphide lenses persist laterally for over 3 km east of the trachyte dome at approximately the same stratigraphic level, indicating widespread, stable conditions for sulphide deposition.

Chzerpnough (Fire)

The Chzerpnough (Fire) prospect (Fig. 32; Yukon MINFILE, 2001, 105F 071; 61°36'44"N; 132°26'05"W; NTS 105F/9) is underlain by felsic metavolcanic rocks of early Mississippian age (Mortensen, 1982), similar to those in other areas of the PMVB. Bands of disseminated pyrite and galena occur within sucrosic barite and up to 15% pyrite occurs within metarhyolite (Kreft, 1997b). Diamond drilling intersected barite containing variable amounts of silver-lead-zinc mineralization over apparent thicknesses of 5.3 to 15.1 m. Results include 15.1 m of 22.4 g/t Ag, 1529 ppm Pb and 6033 ppm Zn (Eagle Plains Resources Ltd., 2000).

Geology

Rocks underlying the Chzerpnough property include metamorphosed foliated felsic lapilli tuffs, felsic flows, sills and/or dykes and lesser well-bedded, poorly foliated volcaniclastic strata. Overall, in outcrop the volcanic rocks weather rust coloured to green to black, with dominantly pale to medium grey fresh surfaces. Fine-grained, commonly crystalline pyrite is disseminated throughout. The rocks vary from intensely to weakly foliated, are generally sericitized and/or ferroan-carbonate-altered, commonly with limonitic blebs. The rocks are dominantly tuffaceous and vary from clast- to matrix-supported with clasts that average 0.5 to 2 cm across, and reach a maximum of 0.6 m (Fig. 35c). Clasts are generally flattened parallel to foliation, and are locally angular to sub-rounded. Foliation is bent around large clasts. In general, the clasts are fine-grained and vary from pale grey to green to cream. Rarely they are flow-banded or quartz phyric.

Medium to fine lapilli tuff (Appendix VI-3: specimens JH96-5F,10A,13A, B, C) contains subangular to subrounded clasts up to 1.5 cm in diameter. The clasts are composed of variably altered alkali feldspar, quartz, sericite and carbonate in a matrix composed dominantly of sericite or carbonate with variable amounts of barite, pyrite, quartz and/or alkali feldspar. Fractures which cross-cut some fragments (Appendix VI-3: specimen JH96-5F) are coated with sericite and barite ± pyrite suggesting at least some mineralization may be late (epigenetic) rather than syngenetic.

Fine-grained lapilli tuff (Appendix VI-3: specimens JH96-2C, 6A, 7A) contains flattened shards, <0.5 cm across, composed of sericite with minor alkali feldspar, or replaced by carbonate, in a matrix composed dominantly of sericite or carbonate with lesser pyrite, quartz and/or alkali feldspar. Local limonite blebs may be relict sulphide clasts (e.g., Appendix VI-3: specimen JH96-2C).

Several larger clasts within the metatuffs are composed dominantly of alkali feldspar laths partly altered to sericite ± carbonate (Appendix VI-3: specimen JH96-10B). Others are composed of matrix-supported, fine- to medium-grained lapilli tuff with fragments composed mainly of carbonate in a sericite matrix (Appendix VI-3: specimen JH96-12C).

Locally, the tuffaceous rocks are cut by numerous quartz veinlets, and contain rare calcite-fluorite blebs, quartz phenocrysts and autobreccia. Some of the tuffaceous rocks are bleached and oxidized to pale yellow or orange weathering lenses up to 3 m thick and 5 m long. Within these lenses the rocks are locally silicified and brecciated, or pyrite-rich with bands, blebs and lenses of fine-grained massive pyrite up to 5 cm thick. Locally, thin-bedded (1 to 20 cm), laminated (alternating siliceous and non-siliceous) possibly metasedimentary rocks about 2 m thick occur within the tuffaceous package.

Non-fragmental felsic volcanic flows or sills occur rarely within the fragmental rock package. They are cut locally by abundant quartz ± alkali feldspar-carbonate-limonite veins (Appendix VI-3: specimen JH96-2A) and replaced locally by areas of carbonate-limonite after sulphide and sericite.

Overlying the volcanic rocks on the Chzerpnough (Fire) property are at least 50 m of metavolcaniclastic strata. They are rusty-weathering, poorly foliated and distinctly bedded with beds 2 to 20 cm thick. In general, the strata vary from fine- to coarse-grained with fragments 1 to 2 cm long and 1 cm wide; locally the fragments are up to 10 cm across. The coarser grained beds weather rusty orange and have ferroan carbonate alteration. Locally, the strata are fine-grained, laminated and maroon. The volcaniclastic strata are cut locally by quartz veinlets. Crude grading and sparse scours suggest the strata are right-way-up with tops to the northeast at this location. Within this volcaniclastic package are strata at least 25 m thick that appear to be vesicular. These strata may be flows. However, the apparent vesicularity may be due to weathered-out carbonate blebs and unrelated to vesiculation.

Most rocks in this area have been variably sericitized and/or replaced by ferroan carbonate. A large part of this alteration is likely due to metamorphism. However some of the sericite may be due to hydrothermal alteration related to proximity to a submarine volcanic vent (Dickie, 1996a; Leitch, 1998). Rocks on the Fire property are predominantly quartz-sericite-pyrite-altered with local chlorite and rare fluorite (Downie, 2000). Diamond drill hole F00-01 intersected a zone of pervasive hematite-silica-epidote alteration, and a zone of locally intense potassium feldspar flooding and veining (ibid.)

Exploration techniques

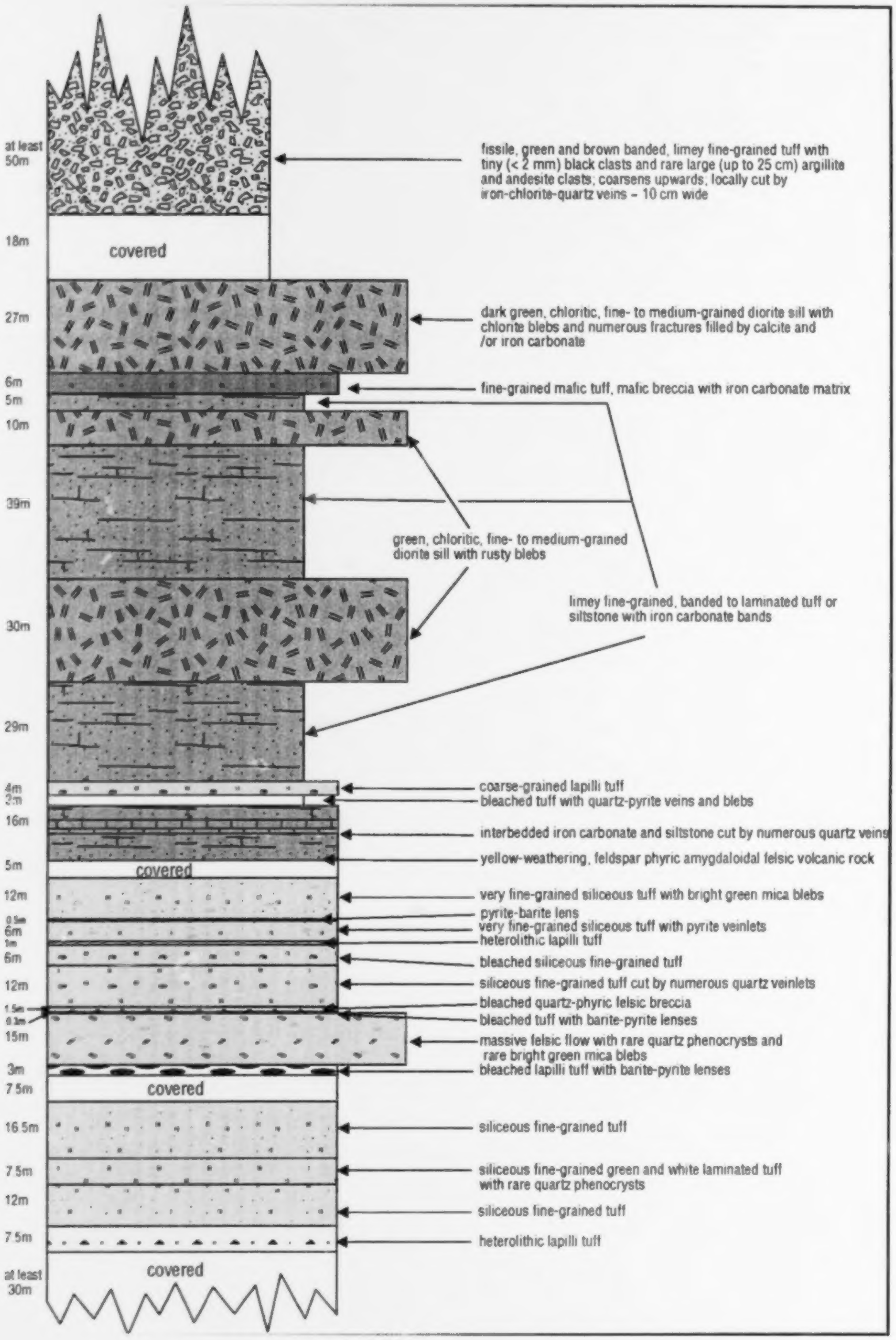
Geochemistry: A geochemical trend, reflected by elevated zinc, lead, silver and copper values in talus fines was defined by Eagle Plains Resources Ltd. in 1996 (Downie, 2000). Coincident barium-mercury-lead-zinc soil geochemical anomalies were identified by Atna Resources Ltd. in 1998. These geochemical anomalies are associated with a widespread package of silica- and sericite-altered intermediate to felsic metamorphosed volcanic and volcaniclastic rocks containing pyrite, barite and galena.

Geophysics: Magnetic intensity is subdued in this area and is indicative of sedimentary and felsic volcanic rocks (McGill et al., 1998). Several significant electromagnetic anomalies have been identified. Magnetic linears, interpreted from vertical gradient maps, may represent high-angle faults.

Tree

The Tree property (Fig. 32; Yukon MINFILE, 2001, 105F 095; 61°38'23"N; 132°25'18"W; NTS 105F/9) lies about 2 km northeast of the Chzerpnough (Fire) property. Claims in this area were staked to cover anomalous zinc and copper values returned by reconnaissance stream sediment samples (Wilson and Westerman, 1978). The area is underlain by black shales overlain by intermediate to felsic metavolcanic flows and tuffs with complex lateral facies changes. The Tree property is underlain by at least two intermediate to felsic volcanic cycles (Schmidt, 1998). The lower volcanic cycle includes metamorphosed andesite, dacite, rhyodacite and rhyolite. The upper volcanic cycle comprises primarily andesitic lapilli metatuffs with minor metaflows and interbedded lenses of phyllite, metasiltstone and associated meta-epiclastic rocks. Mafic metaflows and felsic metatuffaceous rocks also occur within this

***Figure 36.** Stratigraphic section for the Tree property (Fig. 32) at the northern end of the Pelly Mountains volcanic belt.*


at least 50m
fissile, green and brown banded, limey fine-grained tuff with tiny (< 2 mm) black clasts and rare large (up to 25 cm) argillite and andesite clasts; coarsens upwards; locally cut by iron-chlorite-quartz veins ~ 10 cm wide
18m
covered
27m
dark green, chloritic, fine- to medium-grained diorite sill with chlorite blebs and numerous fractures filled by calcite and /or iron carbonate
6m
fine-grained mafic tuff, mafic breccia with iron carbonate matrix
5m
10m
39m
green, chloritic, fine- to medium-grained diorite sill with rusty blebs
limey fine-grained, banded to laminated tuff or siltstone with iron carbonate bands
30m
29m
4m
coarse-grained lapilli tuff
2m
bleached tuff with quartz-pyrite veins and blebs
16m
interbedded iron carbonate and siltstone cut by numerous quartz veins
yellow-weathering, feldspar phyric amygdaloidal felsic volcanic rock
5m
covered
12m
very fine-grained siliceous tuff with bright green mica blebs
0.5m
pyrite-barite lens
6m
very fine-grained siliceous tuff with pyrite veinlets
1m
heterolithic lapilli tuff
6m
bleached siliceous fine-grained tuff
12m
siliceous fine-grained tuff cut by numerous quartz veinlets
1.5m
bleached quartz-phyric felsic breccia
0.3m
bleached tuff with barite-pyrite lenses
15m
massive felsic flow with rare quartz phenocrysts and rare bright green mica blebs
3m
bleached lapilli tuff with barite-pyrite lenses
7.5m
covered
16.5m
siliceous fine-grained tuff
7.5m
siliceous fine-grained green and white laminated tuff with rare quartz phenocrysts
12m
siliceous fine-grained tuff
7.5m
heterolithic lapilli tuff
at least 30m
covered

cycle but their relationship to the andesitic metatuffs is not clear. Figure 36 shows a section through part of the strata exposed on the Tree property.

Mineralization

Locally, rhyodacite metaflows are heavily pyritized and/or geochemically anomalous in zinc where brecciated. Locally, the breccias contain anomalous barium associated with sparse galena and sphalerite mineralization. Weak zinc mineralization also occurs locally as fracture fillings within rhyodacite metaflows and metatuffs (Norman and Vyselaar, 1979). Locally, cross-cutting quartz veins also contain minor galena and sphalerite (ibid.). In this area pyritiferous trachyte sills produce spectacular gossans, but are not considered to have economic significance.

Geochemistry and geophysics

The lower volcanic cycle of Schmidt (1998) is associated with anomalous barium and lead values. The upper cycle is associated with elevated zinc levels. A water sample collected from a creek draining the Chzerpnough property returned elevated values of lead and zinc, plus nickel, cadmium and sulphate (water sample # 179 in Hunt, 1999b).

An electromagnetic (EM) survey outlined a large conductive area probably caused by pyritiferous metarhyodacite units occurring within 10 m of surface (Schmidt, 1998). Max-Min geophysical surveys outlined several conductors within yellow-weathering trachyte.

Bnob (Ice)

The Bnob (Ice) occurrence (Fig. 32; Yukon MINFILE, 2001, 105F 073; 61°34'28"N; 132°32'02"W; NTS 105F/10) is located about 7 km southwest of Chzerpnough (Fire). The property is underlain by strongly pyritic felsic metavolcanic breccias associated with lead and zinc soil geochemical anomalies and barite.

Geology

Bnob (Ice) is underlain by a package of ash to lapilli metatuffs that contain up to 5% disseminated pyrite. The tuff package is overlain by layered, sucrosic, white to pale grey barite with minor disseminated pyrite and galena. Overlying the barite is a strongly foliated, moderately to intensely sericite-altered unit of fine-grained lapilli metatuff with rare fragments of massive pyrite. This is overlain by pyritic metatrachyte, which is in fault-contact with a fine- to medium-grained, sill-like syenite body (Dickie, 1997; Wilson and Holbek, 1999).

Mineralization

There are several mineralized showings on the property (Wilson and Holbek, 1999; Downey, 2000).

1. The Bnob showing is a northeast-trending, northwest-dipping, sucrosic, stratiform bedded barite body up to 9 m thick and 4 m wide that is exposed in outcrop and trenches for over 250 m (Fig. 35d). The barite occurs within pyrite-lapilli metatuff and pyritic metatrachyte and contains 0.5 to 1.0% blebs and disseminations of galena and finely disseminated pale-coloured sphalerite (ibid.; Dickie, 1996b). This showing is reflected by anomalous zinc and lead soil geochemistry that defines a trend parallel to the foliation or bedding. Samples of this showing returned elevated levels of zinc, lead and silver. A co-planar horizontal-loop electromagnetic (HLEM) geophysical survey identified two moderate conductors that are indicative of a fault zone and a graphitic argillite horizon.
2. The Greig showing occurs about 1 km from the Bnob showing at the toe of a talus field dominated by syenite boulders. It consists of bedded barite that contains sphalerite, galena and pyrite (Downie, 2000). Drillhole I00-01, on the Greig showing, intersected syenite underlain by metavolcanic rocks. The metavolcanic rocks include pyritic lapilli tuff and heterolithic breccia and debris flows. Massive to semi-massive, flat-lying, barite (32 m true thickness) occurs within the volcanic sequence. The barite occurs as thin laminated intervals and as replacement of volcanic rocks (Downie, 2000). Samples of the horizon returned average values of 8.9 g/t Ag, 5019 ppm Zn and 1659 ppm Pb over 48 m. The best mineralized interval is 1.3 m thick and returned 5.64% Zn, 0.17% Pb and 12.3 g/t Ag (Eagle Plains Resources Ltd., 2000). The barite horizon grades downhole into a series of thinner horizons within pyritic lapilli tuff (Downie, 2000).
3. An unnamed showing consisting of a barite horizon, approximately 10 m thick, that contains banded galena and sphalerite. This barite horizon occurs immediately above the contact between argillite and overlying metavolcanic rocks (Dickie, 1996b). Samples of mineralized barite returned values of up to 12.7% Pb, 4.7% Zn and 55 g/t Ag (Kreft, 1997a; Eagle Plains Resources Ltd., 1997).

4. The Ice 1 showing that consists of a large boulder of massive crystalline barite with trace chalcopyrite, locally cut by veinlets of galena and sphalerite (ibid.).
5. The Gulley zone is an area of anomalous lead and zinc soil geochemistry.

Mamu

The Mamu property (Fig. 32; Yukon MINFILE, 2001, 105F 013; 61°28'27"N; 132°27'38"W; NTS 105F/8) is underlain by Mississippian metavolcanic and metasedimentary rocks intruded by a Mississippian metaintrusive complex of syenite, monzonite, quartz monzonite, diorite and gabbro (Doherty, 1997). The metavolcanic-sedimentary package comprises variably altered intermediate and felsic metavolcanic rocks, argillite and phyllite. The dominant alteration is a phyllic assemblage of quartz-sericite-carbonate-pyrite (ibid.). Locally, secondary biotite or chlorite are present in significant amounts.

Mineralization consists of disseminated pyrite in meta-exhalite horizons, massive bedded pyrite, quartz veins, and quartz breccia with pyrite ± sphalerite, tetrahedrite, galena and chalcopyrite (ibid.). The main showing is a massive pyrite horizon 1.0 to 1.8 m thick. Most sulphides have been oxidized to limonite and other iron oxides.

Vermilion

The Vermilion showing (Fig. 32; Yukon MINFILE, 2001, 105G 141; 61°21'48"N; 131°33'12"W; NTS 105G/5) is a new prospect located about 4.2 km northwest of Mount Vermilion. The showing consists of massive sulphide boulders in a creek. The boulders contain bands of massive pyrite several centimetres thick in fine-grained, siliceous trachyte, and massive 'frothy' pyrite with fragments of trachyte. Samples of the boulders returned values of up to 765 ppm Pb and 14 ppm Zn (Appendix VI-2: samples JH98-AI, AII).

SELWYN BASIN

In the Selwyn Basin minor amounts of Devonian and Mississippian metavolcanic rocks occur within the dominantly sedimentary Earn Group. The metavolcanic rocks in the Selwyn Basin are associated with VMS mineralization at the Marg deposit and Jane zone and possibly the Primo occurrence which are described below (cf. Turner and Abbott, 1990; Gordey, 1990; Goodfellow et al., 1995).

MINERAL DEPOSITS/OCCURRENCES

Marg

The Marg deposit (Figs. 32, 37; Yukon MINFILE, 2001, 106D 009; 64°08'21"N, 134°27'54"W; NTS 106D/1) has an indicated and inferred resource of 5.527 million tonnes grading 1.76% Cu, 2.46% Pb, 4.60% Zn, 62.7 g/t Ag and 0.98 g/t Au (NDU Resources Ltd., 1996). It occurs within a thrust panel between the Robert Service and Tombstone thrust faults in north-central Selwyn Basin (Abbott, 1990a,b). The mineralization lies within a 4-km-long east-trending fault repetition or recumbent infold of deformed probable early Mississippian phyllite of the Earn Group sandwiched between layers of Keno Hill Quartzite (Abbott, 1990a,b; Turner and Abbott, 1990; Gish, 1998).

Property and deposit geology

The Marg property is underlain by a basal sequence of monotonous grey quartzite interlayered with lesser quartz-graphite phyllite and minor quartz-muscovite phyllite (Unit 1 on Figs. 38 and 39). This is overlain by a package composed of approximately equal amounts of quartz-muscovite and quartz-graphite phyllite with lesser carbonate, quartzite, quartz-chlorite and chlorite-muscovite phyllite (Unit 2b on Figs. 38 and 39; Gish, 1998) that hosts the mineralization. The contact between Units 1 and 2b is marked by a zone, several metres wide, of intensely foliated rock, boudinaged quartzite beds and/or zones of graphitic gouge. MacLellan and Carne (1990) interpret this as a thrust fault that steepens up-dip and truncates the mineralization to the east at surface. The mineralization-hosting package is overlain by a sequence primarily made up of quartz-graphite phyllite with lesser quartz-muscovite phyllite (Unit 2c). This sequence is, in turn, overlain (structurally) by a unit consisting of equal amounts of quartz-muscovite and quartz-graphite phyllite and quartzite, with minor quartz-carbonate lenses and layers (Unit 3a). The contact between Units 2c and 3a is a fault marked by a 2- to 5-m-thick zone of fault gouge and brecciated rock (MacLellan and Carne, 1990; Gish, 1998). This structure roughly parallels compositional layering at the east end of the deposit but cuts down-section to the west (MacLellan and Carne, 1990).

At least two phases of regional penetrative deformation have affected the above rocks (Turner and Abbott, 1990), but they appear to be uniformly homoclinal. Foliation is consistent at 050-080/50 SE with a rodding lineation of 120-135/50 (Gish, 1998). Most of the above strata have been intruded by gabbroic to dioritic sills that are correlated with rocks of probable Triassic age in the Ogilvie Mountains (Mortensen and Thompson, 1989).

Lithologies

Following are descriptions of individual lithologies within the units described above and shown on Figures 38 and 39. All petrographic descriptions are summarized from Leitch (1998, Appendix VI-3) unless otherwise specified.

Quartzite (QZIT on Fig. 39) is highly resistant and, together with greenstone, forms most of the ridges on the property. It is dominant in the footwall to the mineralized sequence (Unit 1) but also occurs within unit 3. The quartzite is pale to medium grey, fine-grained and thin-bedded to massive. Where bedded, 0.15- to 3-m-thick

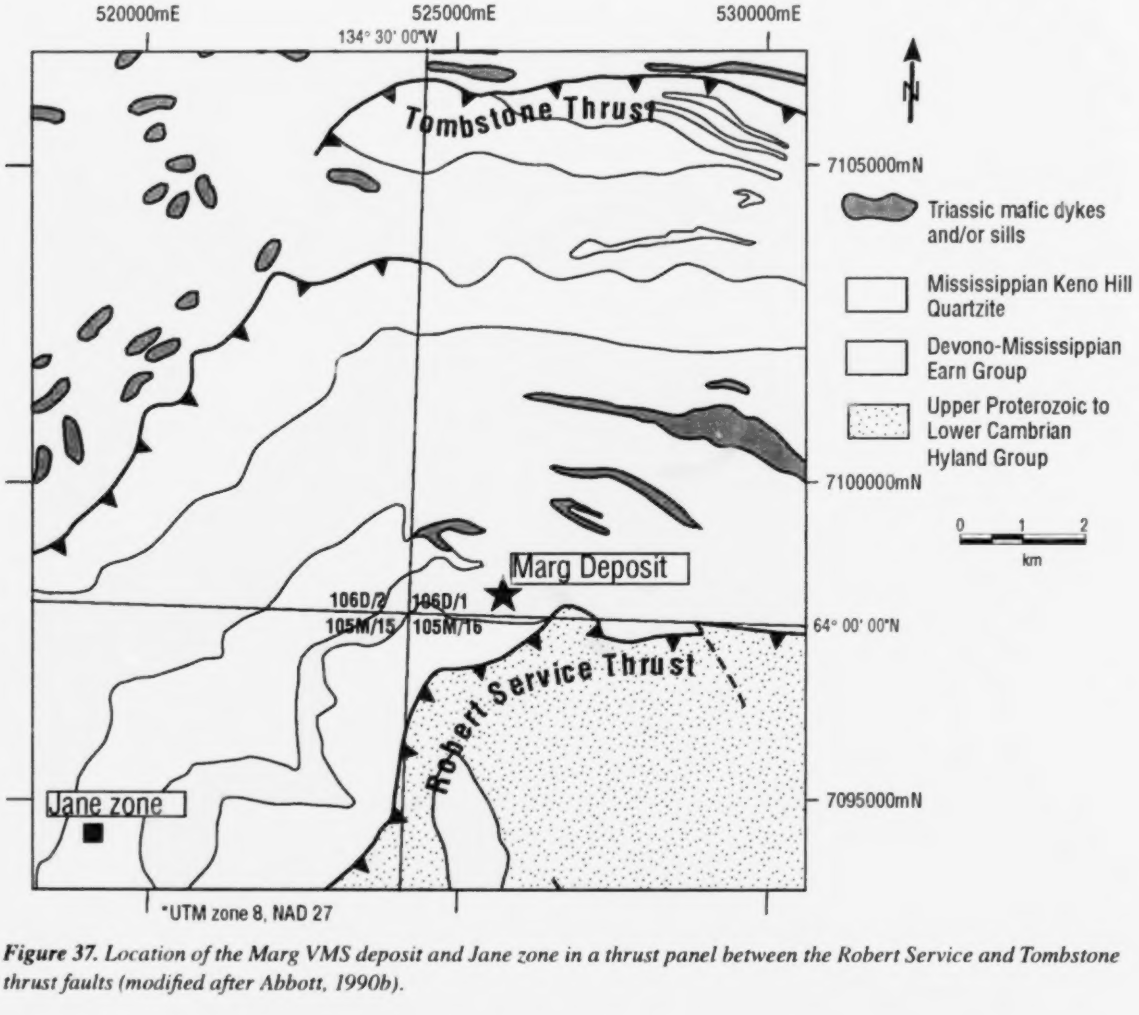

520000mE
525000mE
530000mE
134° 30' 00"W
Tombstone Thrust
N
7105000mN
Triassic mafic dykes and/or sills
Mississippian Keno Hill Quartzite
Devono-Mississippian Earn Group
Upper Proterozoic to Lower Cambrian Hyland Group
7100000mN
0
1
2
km
Marg Deposit
106D/2
106D/1
105M/15
105M/16
64° 00' 00"N
Robert Service Thrust
7095000mN
Jane zone
*UTM zone 8, NAD 27

Figure 37. *Location of the Marg VMS deposit and Jane zone in a thrust panel between the Robert Service and Tombstone thrust faults (modified after Abbott, 1990b).*

quartzite is interlayered with black graphitic phyllite (MacLellan and Carne, 1990; Turner and Abbott, 1990; Gish, 1998).

This lithology is made up of quartz (± limonite ± tourmaline ± sericite ± carbonate ± pyrite ± zircon ± (?)carbon ± rutile) schist composed of fine-grained quartz with wispy foliae defined by sericite and opaques plus tourmaline, rutile and zircon (Appendix VI-3: specimens DDH 96-48-13.5 m, 376 m, 413.4 m). The protolith for this rock type was probably siliceous clastic sediment. Locally, the interlayered nature of quartzite and phyllite suggests deposition as mud and fine-grained quartz sand by turbidity currents (Turner and Abbott, 1990; MacLellan and Carne, 1990; Gish, 1998). Samples from Units 1 and 3a contain subhedral to rounded grains of, probably detrital, green tourmaline suggesting they may share a similar provenance.

Quartz-graphite phyllite (QGPH on Fig. 39) occurs primarily within Units 2c and b, and is described by MacLellan and Carne (1990) as the major unit in drill core and the one that is associated with the massive sulphides. It is a recessive, sooty lithology that contains up to 55% very fine-grained quartz-sericite laminae and up to 10% euhedral pyrite crystals, and which generally contains a high abundance of deformed metamorphic quartz veins or "sweats" (MacLellan and Carne, 1990; Gish, 1998).

Leitch (1998) describes the following rock types within the quartz-graphite phyllite: 1) quartz-sericite-

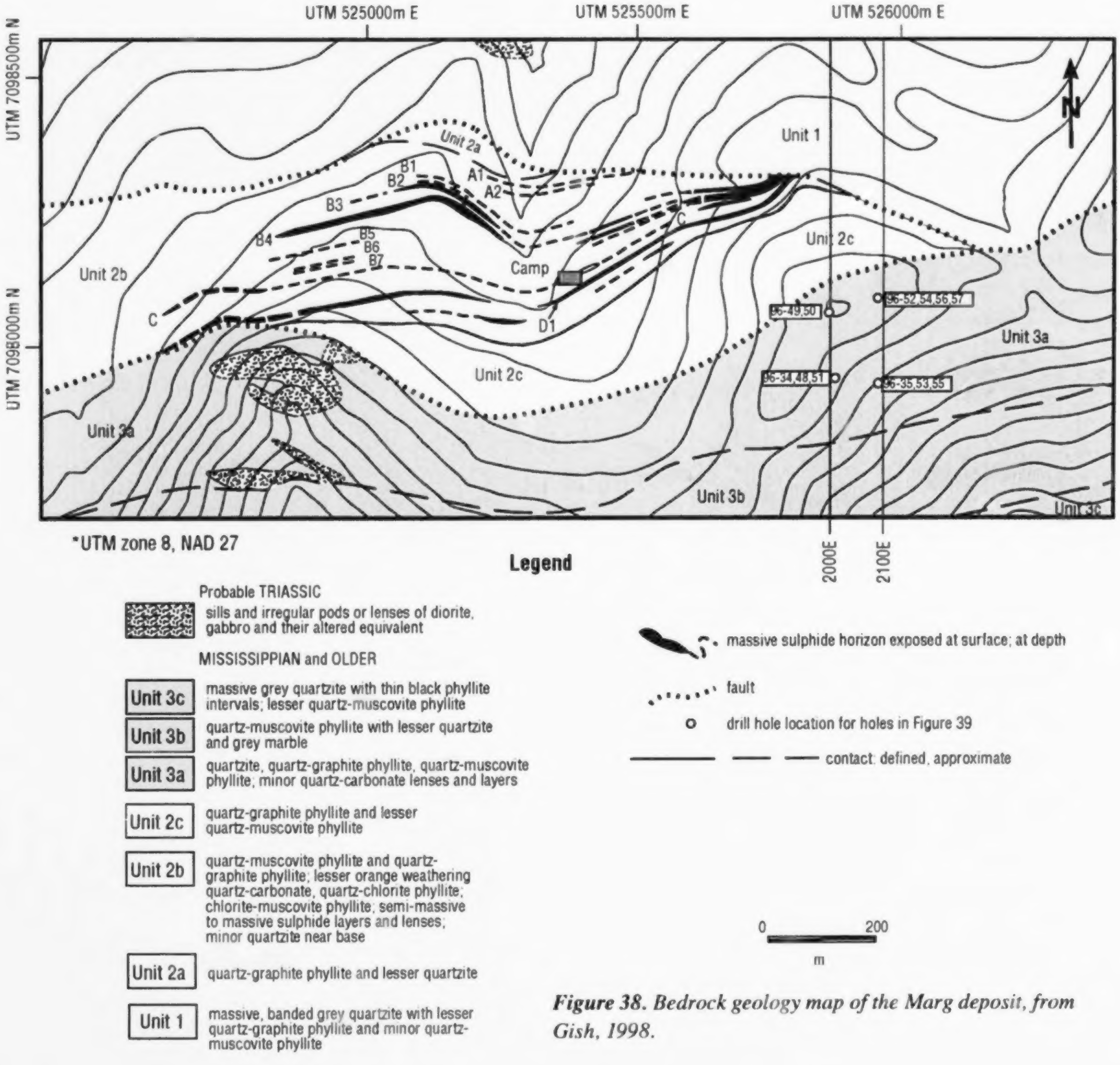
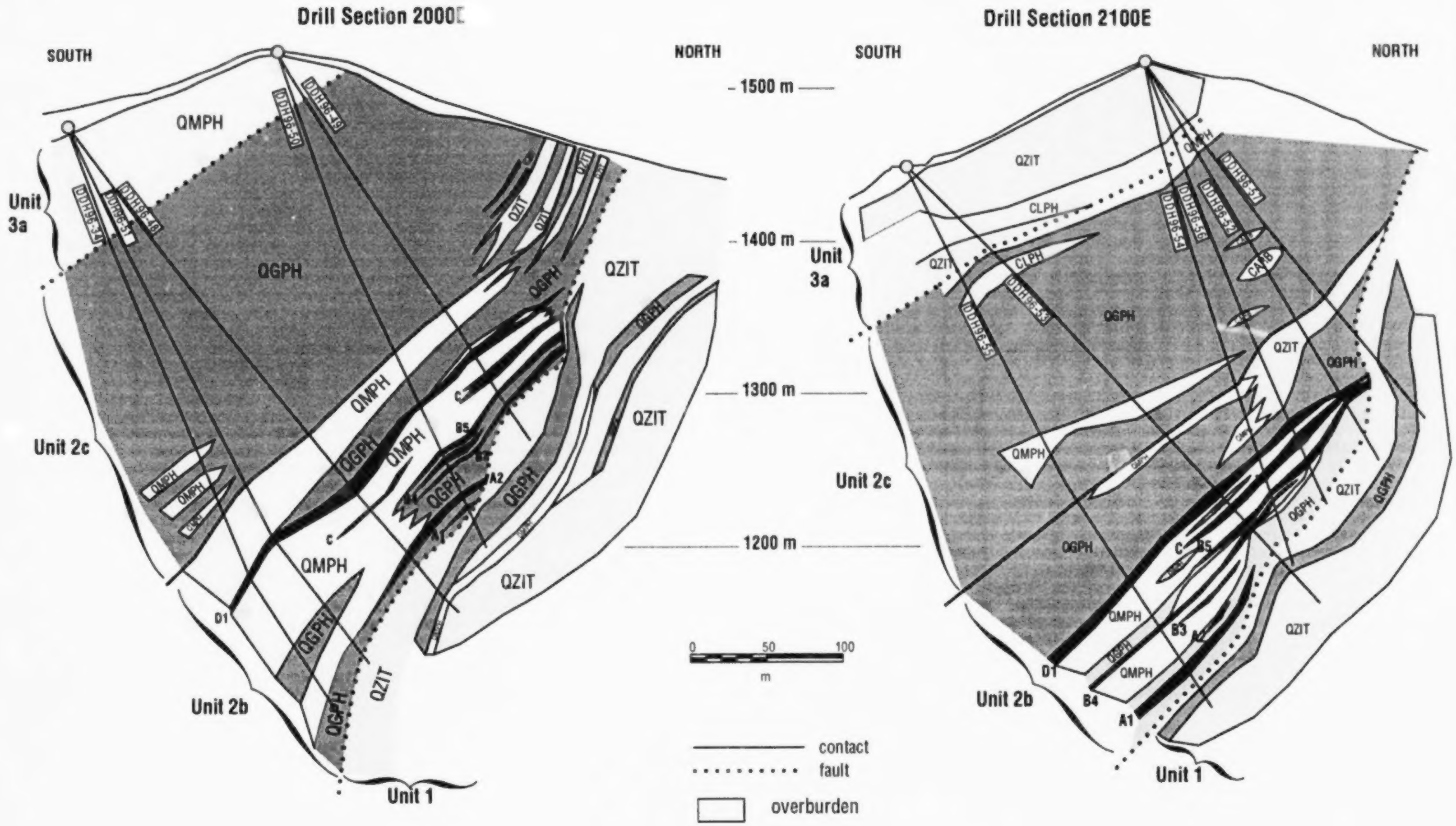

UTM 525000m E
UTM 525500m E
UTM 526000m E
UTM 7098500m N
UTM 7098000m N
N
Unit 2a
Unit 1
B1
B2
A1
A2
B3
B4
B5
B6
B7
C
Unit 2c
Unit 2b
Camp
D1
96-49,50
96-52,54,56,57
Unit 3a
96-34,48,51
96-35,53,55
Unit 2c
Unit 3a
Unit 3b
Unit 3c
*UTM zone 8, NAD 27
2000E
2100E
Legend
Probable TRIASSIC
sills and irregular pods or lenses of diorite, gabbro and their altered equivalent
MISSISSIPPIAN and OLDER
Unit 3c
massive grey quartzite with thin black phyllite intervals; lesser quartz-muscovite phyllite
Unit 3b
quartz-muscovite phyllite with lesser quartzite and grey marble
Unit 3a
quartzite, quartz-graphite phyllite, quartz-muscovite phyllite; minor quartz-carbonate lenses and layers
Unit 2c
quartz-graphite phyllite and lesser quartz-muscovite phyllite
Unit 2b
quartz-muscovite phyllite and quartz-graphite phyllite; lesser orange weathering quartz-carbonate, quartz-chlorite phyllite; chlorite-muscovite phyllite; semi-massive to massive sulphide layers and lenses; minor quartzite near base
Unit 2a
quartz-graphite phyllite and lesser quartzite
Unit 1
massive, banded grey quartzite with lesser quartz-graphite phyllite and minor quartz-muscovite phyllite
massive sulphide horizon exposed at surface; at depth
fault
drill hole location for holes in Figure 39
contact: defined, approximate
0
200
m

Figure 38. Bedrock geology map of the Marg deposit, from Gish, 1998.


Drill Section 2000E
SOUTH
NORTH
Unit 3a
Unit 2c
Unit 2b
Unit 1
QMPH
QGPH
QZIT
DDH96-34
DDH96-51
DDH96-48
DDH96-50
DDH96-49
C
B5
A2
D1
1500 m
1400 m
1300 m
1200 m
Drill Section 2100E
SOUTH
NORTH
QZIT
CLPH
CARB
DDH96-55
DDH96-53
DDH96-54
DDH96-56
DDH96-52
DDH96-57
B3
B4
A1
0
50
100
m

- contact
- .... fault
- ☐ overburden
- CARB carbonate
- QMPH quartz-muscovite phyllite
- CLPH quartz-chlorite phyllite
- QGPH quartz-graphite phyllite
- QZIT quartzite
- ■ massive sulphide horizon

Figure 39. *Drill sections for the Marg deposit (modified from Gish, 1998). Only drill holes from 1996 are shown. Samples from drill holes are described in Appendix VI-4. Locations of drill holes are shown on Figure 38.*

ferroan carbonate-pyrite-(?)carbon (± tourmaline ± rutile ± limonite) schist, 2) quartz-ferroan carbonate-sericite-pyrite-(?)carbon schist, 3) quartz-(?)graphite-ferroan carbonate-sericite schist and 4) sericite-opaques (carbon, rutile)-minor quartz-carbonate-pyrite schist (Appendix VI-3: specimens DDH 96-48-28.31 m; DDH 96-49-270 m, 273.1 m; DDH 96-48-301 m; DDH 96-48-130.15 m, respectively). In general the rocks are made up of fine-grained, finely laminated quartz (white) and sericite with pyrite and carbon (black) interlaminations. Protoliths were likely siltstone and/or sedimentary or volcaniclastic rocks of intermediate composition (Leitch, 1998 in Appendix VI-3), or interbedded black carbonaceous shale and chert (Gish, 1998). Turner and Abbott (1990) describe this unit as black, siliceous pyritic metachert whose deposition likely coincided with the formation of the massive sulphides; its composition may reflect pelagic or hydrothermal silica and organic matter accumulation in an anoxic basin.

Quartz-muscovite phyllite (QMPH on Fig. 39) occurs within all of the above units and encompasses a wide range of textural and compositional varieties. Most common is a strongly foliated rock made up largely of muscovite (or sericite) and quartz, with varying amounts of carbonate, dolomite and chlorite; locally carbonate-rich varieties of this lithology occur in beds up to 2 m thick (Gish, 1998).

This lithology includes quartz-sericite-ferroan carbonate schist, quartz-sericite-chlorite-ferroan carbonate schist, and sericite-quartz-ferroan carbonate schist as described below.

- Quartz-sericite-ferroan carbonate (± pyrite ± sphalerite ± rutile) schist is dominant and is composed of approximately 55-75% quartz, 15-35% sericite, 5-7% carbonate (ankerite ± dolomite), 0-7% opaques (pyrite ± chalcopyrite ± (?)carbon), 0-<1% rutile and 0-1% sphalerite (Appendix VI-3: specimens DDH 96-48-17.93 m, 360.75 m; DDH 96-49-235.3 m, 242.05 m, 262.48 m; DDH 96-56-257.8 m). The sphalerite is dominantly pale coloured. Protoliths were probably intermediate or felsic rock or exhalite. Sample DDH 96-49-242.05 m has (?)relict quartz, plagioclase and mafic phenocrysts, which combined with the presence of rutile suggest this rock may originally have been an intermediate or felsic porphyritic rock. Sample DDH 96-56-257.8 m is similar to DDH 96-49-242.05 m but lacks the quartz phenocrysts of the latter. It is from within the 'D' sulphide horizon (Fig. 39) and may be metaexhalite; it is composed of 60% quartz, 25% sericite, 7% carbonate, 7% pyrite, 1% sphalerite (pale) and <1% rutile .
- Quartz-sericite-chlorite-ferroan carbonate (± pyrite ± rutile) schist is composed of approximately 50-60% quartz, 20-25% sericite, 10-25% chlorite, 2-10% carbonate, <1-2% opaques (pyrite ± possible carbon) and <1% rutile (Appendix VI-3: specimens DDH 96-48-89.54 m, 210.6 m, 270 m, 310.05 m, 312.65 m, 338.92 m, 401.32 m). Specimen DDH 96-48-401.32 m contains sericite aggregates, that likely represent former plagioclase crystals, and relict garnet. Sample DDH 96-48-89.54 m contains carbonate porphyroblasts. Specimen DDH 96-48-312.65 m is from beneath the 'D' sulphide horizon and contains 30% magnesian chlorite suggesting footwall alteration. Turner and Abbott (1990) describe distinctive green chlorite-bearing schists from below the sulphide horizon in DDH 88-23 to the east. Protoliths for the quartz-sericite-chlorite-ferroan carbonate (± pyrite ± rutile) schist were probably intermediate volcanic rocks. Sample DDH 96-48-210.6 m is from within QGPH (see below) and is carbonate-rich (40%) with 20% chlorite and only 20% quartz, suggesting a possible mafic precursor.
- Sericite-quartz-ferroan carbonate (± pyrite ± sphalerite) schist consists of approximately 70% sericite, 20% quartz, 5% carbonate, 3-5% pyrite, <1% rutile and <1% sphalerite (pale; Appendix VI-3: specimen DDH 96-48-325.8 m). This sample contains carbonate porphyroblasts. Based on the high sericite content, the protolith was possibly a felsic feldspar-rich rock or a clay-rich exhalite.

Other sericite-rich schists occur about 500 m to the east of the above samples and are described by Turner and Abbott (1990) as the major lithology below the ore horizon in the core of the Marg fold in that area. Turner and Abbott (1990) interpret carbonate-quartz bands within this sericite-rich zone to represent a stockwork of quartz-carbonate veinlets that likely formed in an upflow zone or vent complex.

Quartz-chlorite phyllite (CLPH on Fig. 39) is yellow-green to grey-green laminated rock generally made up of greater than 50% chlorite with lesser quartz, muscovite and carbonate (Gish, 1998). Chlorite is usually intergrown with muscovite. The protolith may have been intermediate tuff.

Carbonate (CARB on Fig. 39) occurs as buff, grey to locally green, pale-orange-weathering layers made up of

50% ankerite, 15% quartz and 35% muscovite (Gish, 1998). Textures suggest that this unit is recrystallized felsic tuff. Thin, relatively continuous beds of grey marble are also present.

Chlorite-muscovite phyllite (not shown on Fig. 39) is commonly blue-green and composed of up to 50% chlorite, up to 40% quartz and minor muscovite with quartz-ferroan carbonate veins. This lithology also includes dark green massive chloritic varieties (Gish, 1998). It is spatially related to the C and D massive sulphide horizons, and may be an alteration product of QMPH (Gish, 1998). In drill core MacLellan and Carne (1990) describe it as forming thin beds that are closely associated with quartz-sericite phyllite (QMPH) and massive sulphide intervals. They describe similar outcrops that occur in the vicinity of soil geochemical anomalies. These outcrops represent the only indication of mineralization at surface.

Preliminary lithogeochemistry

Two of the samples collected for lithogeochemistry have potential metavolcanic protoliths (Appendix VI-2: specimens DDH96-48-360.75 m, 401.32 m). Specimen DDH96-48-360.75 m is from QMPH immediately overlying semi-massive sulphides in the A2 horizon (Fig. 39). This sample is made up of quartz-sericite-ferroan carbonate-pyrite-(?)carbon schist with trace rutile and zircon. The sample contains quartz crystals, which may represent former quartz phenocrysts, and carbonate porphyroblasts of probable metamorphic origin. On a plot of Zr/TiO_2 versus Nb/Y this sample plots within the rhyolite field (Fig. 40a). On a plot of Nb versus Y, it plots in the within-plate-granite field (Fig. 40b).

Specimen DDH96-48-401.32 m is from QMPH below the known mineralization. This sample is made up of quartz-sericite-chlorite-ferroan carbonate schist with minor pyrite, carbon, rutile and garnet. The sample contains sericite and carbonate aggregates that were likely plagioclase and garnet crystals, respectively (Leitch, 1998 in Appendix VI-3). On a plot of Zr/TiO_2 versus Nb/Y this sample plots in the rhyodacite/dacite field (Fig. 40a). On a plot of Nb versus Y it lies within the volcanic arc and syn-collisional granite field (Fig. 40b). On a chondrite-normalized REE plot, sample 360.75 m is enriched in all elements compared to sample 401.32 m, and has a greater negative europium anomaly (Fig. 40c).

Mineralization

The Marg deposit consists of up to 12 discontinuous sheet-like, stacked, subparallel, moderately inclined, massive sulphide bodies that have been traced for 1200 m along strike and 600 m down-dip (Gish, 1998). The sulphide bodies are grouped into four major horizons based on proximity, similar mineralization and host lithologies, and are known from bottom to top as A, B, C and D (Figs. 38 and 39). They occur within a 100- to 300-m-thick succession of quartz-sericite (muscovite) phyllite and quartz-graphite phyllite, and commonly occur at breaks between the two rock types (MacLellan and Carne, 1990; Gish, 1998). Mineralized horizons are up to 23 m thick with an average of 3 to 4 m (ibid.). In section 2000E (Fig. 39) the A and D horizons are tabular and relatively continuous. The B and C horizons are less well defined (MacLellan and Carne, 1990). In section 2100E (Fig. 39) all four horizons are well defined.

Cathro (1988) and Turner and Abbott (1990) interpret the sulphide horizons in the eastern part of the deposit to be deformed into an overturned tight to isoclinal fold that verges to the northeast and plunges moderately to the southeast. The upper limb of the sulphide body is interpreted as a single horizon and the lower limb to be made up of several sulphide horizons interlayered with carbonaceous metachert and quartz-sericite schist. The thickest and highest grade intersections and the highest precious metal ratios in horizons D, C and B correlate with this southeast-plunging zone (ibid.). In Horizon A the highest base and precious metal ratios correlate with this zone.

Westward, where the sulphides are made up of up to 12 separate horizons, evidence of folding is less obvious. However, there is some evidence that suggests folding. For example, the upper part of Horizon D and the lower part of B3 each contain rutile (Leitch, 1998 in Appendix VI-3) indicating they may be part of the same horizon, but further work is needed to confirm this.

The mineralization is generally fine-grained and consists mainly of pyrite with lesser sphalerite, chalcopyrite and galena (Fig. 35e; MacLellan and Carne, 1990; Gish, 1998). Tetrahedrite occurs locally in association with galena or chalcopyrite (Gish, 1998), and locally chalcopyrite has overgrown pyrite porphyroblasts suggesting late stage chalcopyrite remobilization. Sphalerite is generally yellow to pale brown. Gangue minerals are primarily quartz and lesser ferroan carbonate and muscovite/sericite (ibid.). In general the sulphides show evidence of metamorphic recrystallization, however, vaguely defined primary layering, laminations and collomorphic and framboidal textures are preserved within the sulphides (Figs. 36f,g; Leitch, 1981a,b, 1990, and

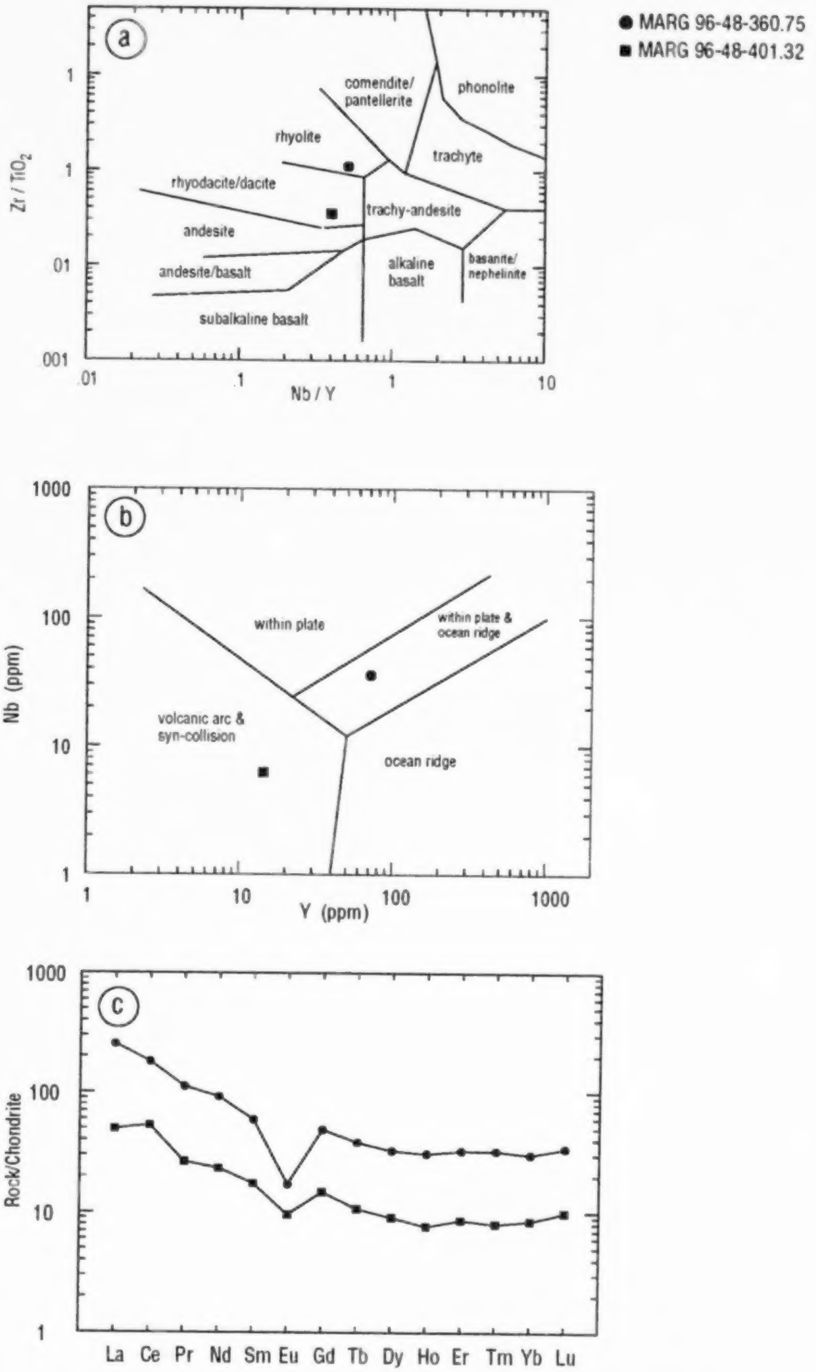


***Figure 40.** Discrimination diagrams and chondrite-normalized REE plot for rocks from the Marg deposit. **a)** and **b)** Discrimination diagrams. **c)** Chondrite-normalized REE plot. a) fields are from Winchester and Floyd (1977); b) fields are from Pearce et al. (1984); c) chondrite normalization values are from Taylor and McLennan (1985).*

Appendix VI-3). These features indicate that these were originally syngenetically precipitated sulphides (ibid.).

The following descriptions of the mineralized horizons include brief petrographic descriptions of individual sulphide horizons generalized from descriptions by Leitch (1998; Appendix VI-3).

The **D horizon** (Fig. 39) is the uppermost of the sulphide horizons and contains much of the known mineralization (MacLellan and Carne, 1990). This horizon is sheet-like, up to 11.2 m thick, and averages 4.0 m thick (Gish, 1998). Eleven samples were collected from this horizon and examined in polished section: five from DDH 96-48 (Appendix VI-3: specimens DDH 96-48-301.23 m, 303.2 m, 306.27 m, 307.76 m and 309.02 m), three from DDH 96-49 (Appendix VI-3: specimens DDH 96-49-237.28 m, 238.65 m and 239.83 m), and three from DDH 96-56 (Appendix VI-3: specimens DDH 96-56-255.25 m, 256.67 m and 257.3 m).

The samples are generally fine-grained, dominantly pyritic, massive to semi-massive sulphides made up of approximately 35-75% pyrite, 2-20% chalcopyrite, 1-10% sphalerite, trace-3% galena, 0-2% tetrahedrite (may include minor tennantite) and 0-10% arsenopyrite in a gangue of quartz, ferroan carbonate (possibly ankerite), sericite and rare chlorite. Arsenopyrite occurs in DDH 96-49 and 56 but not 48. Magnesium chlorite occurs in DDH 96-56.

The **C horizon** underlies the D horizon (Fig. 39), is lens-like (MacLellan and Carne, 1990) to sheet-like and averages 3.7 m thick (Gish, 1998). Six samples were collected from this horizon: two from DDH 96-49 (Appendix VI-3: specimens DDH 96-49-254.45 m and 258.90 m) and four from DDH 96-56 (Appendix VI-3: specimens DDH 96-56-265.33 m, 265.96 m, 268.88 m and 271.85 m).

The samples are generally fine-grained, dominantly pyritic, massive to semi-massive sulphides made up of approximately 30-50% pyrite, 2-20% chalcopyrite, 2-20% sphalerite, trace-3% galena, 0-<1% tetrahedrite (may include minor tennantite) and 0-10% arsenopyrite in a gangue of quartz, ferroan carbonate (possibly ankerite ± dolomite) and sericite. Arsenopyrite occurs in DDH 96-56 but not 49. Magnesium chlorite occurs in one sample in DDH 96-56 (265.96 m).

Sulphides within specimen DDH 96-56-265.96 m have a vaguely fragmental texture with subrounded clasts of fine-grained pyritic material up to 0.5 cm across in a matrix of chalcopyrite, quartz and sericite. This sample also contains aggregates of pyrite that locally display a vague radiating structure typical of early-formed cockscomb-textured marcasite, which is common in known or inferred sea-floor sulphides (see Leitch, 1981a,b, 1990).

The **B horizon** consists of up to seven sulphide lenses (Figs. 38, 39) with an average thickness of 2.6 m (Gish, 1998). The lenses are vertically stacked in three zones within a narrow stratigraphic interval. One sample was collected from the B5 horizon (Appendix VI-3: specimen DDH 96-56-282.82 m) and five from the B3 horizon (Appendix VI-3: specimens DDH 96-49-274.6 m, 276.2 m, 277.32 m, 277.8 m and 280.2 m). The sample from the B5 horizon consists of fine-grained, layered pyritic sulphides in a gangue of quartz, ferroan carbonate (possibly ankerite) and sericite. Layers within this sample, up to 1.5 cm thick, are composed mainly of pyrite with minor chalcopyrite, sphalerite and galena. Less common are layers less than 1 cm thick that are enriched in chalcopyrite and tetrahedrite or composed of quartz, sphalerite, arsenopyrite, chalcopyrite and galena.

Samples from the B3 horizon are generally fine-grained, dominantly pyritic, massive to semi-massive sulphides. The sulphides are made up of approximately 35-60% pyrite, 1-10% chalcopyrite, 2-3% sphalerite, <1-2% galena, 0-2% tetrahedrite (may include minor tennantite) and 0-2% arsenopyrite in a gangue of quartz, ferroan carbonate (possibly ankerite) and sericite with rare garnet (DDH 96-49-276.2 m) and (?)carbon (DDH 96-49-280.2 m). Rare, disseminated rutile occurs at the base of this horizon (DDH 96-49-280.2 m).

Locally, possible fragmental textures are preserved in the B3 horizon. In one sample (DDH 96-49-280.2 m) there are vaguely defined, wispy to lens-shaped possible fragments (or possible boudins) up to 1.5 cm long. In another (DDH 96-49-274.6 m), a vague fragmental texture is evident from wispy, lens-shaped sericite- or possibly quartz-rich clasts up to 0.5 cm in size (Leitch, 1998).

The **A horizon** is the lowermost sulphide horizon and occurs as at least two stacked lenses that average 2.5 m thick (Fig. 39; MacLellan and Carne, 1990; Gish, 1998). No polished section samples were examined from this horizon.

A reinterpretation of Marg geology and mineralization by Atna Resources Ltd. (Holbek et al., 2001) suggests that the deposit occurs within a southeasterly plunging complex fold. They indicate that the mineralization lies within a refolded sheath fold that "appears as an approximate M shape in cross section" (Fig. 41).

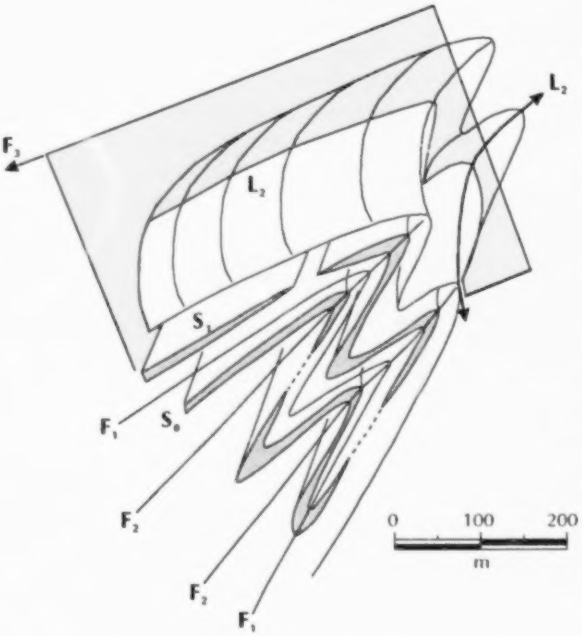


Figure 41. Re-interpreted drill section 2100E for the Marg deposit (Holbek et al., 2001, p. 328).

Exploration techniques

Geochemistry and geophysics

Interest in the Marg area was sparked by the release of results from a Geological Survey of Canada reconnaissance stream sediment survey (Gleeson, 1965a,b). Anomalous values of 205 ppm Pb, 1200 ppm Cu and 2300 ppm Zn were reported from Cansup Creek, which drains the Marg area. The creek was followed about 1.4 km upstream to a large transported gossan with high lead values (up to 1.5%; McLellan and Carne, 1990; Gish, 1997).

Exploration work on the property indicates that two general areas of anomalous soil response are present: 1) a strong lead anomaly (peak values up to 3160 ppm), with a generally subdued copper response and low zinc values, and 2) a 600 x 400 m poorly defined lead, copper and zinc anomaly with values of up to 2250, 1150 and 18 200 ppm, respectively (Gish, 1998). Gish (1998) suggests that the first anomaly is likely due to glacial dispersion from leached and oxidized massive sulphide bodies that subcrop about 200 m east and up-ice of the anomaly. The second anomaly correlates with spring water-iron or exotic gossan deposits which occur at the break in slope just below a 'rock glacier' under which the upper most massive sulphide horizon (D) projects to surface (ibid.).

A pulse electromagnetic survey identified a number of conductors. Some are related to the mineralized horizons and some reflect graphitic horizons. There were no obvious distinguishing features between the two types of conductors. Therefore, the usefulness of this geophysical technique is limited in this area (MacLellan and Carne, 1990).

Jane

The Jane zone lies in a structurally lower thrust panel 7.5 km southwest of the Marg deposit (Fig. 37; MacLellan and Carne, 1990). This zone has anomalous geochemical and geophysical responses plus oxidized massive sulphide float, and stratigraphy similar to that at the Marg (MacLellan and Carne, 1990; Gish, 1998). Interest in the Jane zone was due to the results of a regional geochemical silt (RGS) survey. A silt sample collected during this survey returned values of 240 ppm Pb, 210 ppm Cu and 900 ppm Zn (Gleeson, 1965a,b). Subsequent geochemical sampling has identified discontinuous, but coincident copper, lead and zinc anomalies over a 600 m x 50 to 100 m area (MacLellan and Carne, 1990; Gish, 1998).

VMS POTENTIAL IN SELWYN BASIN ROCKS

The Marg deposit and the nearby Jane zone are the best known VMS occurrences in Devono-Mississippian strata of the Selwyn Basin. However, possible VMS mineralization occurs at the Primo prospect (Yukon MINFILE, 2001, 105H 096) in southern Selwyn Basin near the north end of Frances Lake for which Davidson (1997) describes banded to massive pyrite-pyrrhotite-galena-sphalerite mineralization in chert and argillite overlain by felsic and mafic metatuffs of unknown age. Petrographic examination of a sample of grey-green, vaguely quartz-feldspar-porphyritic rock from the Primo property shows that it is likely sheared, disrupted, possibly originally sericite-altered quartz-feldspar porphyry that could have been a high level intrusive or volcanic rock (Leitch, 1998 in Appendix VI-3).

Also, strata believed to be correlative with those that host the Marg deposit (Unit DMPv of Abbott, 1990a) occur intermittently across central Yukon from Dawson (NTS 116B) to Nahanni (NTS 105I). In the Mayo map area (NTS 105M), Roots (1997) indicates that there are two candidates for analogous strata to those hosting the Marg. The first is gritty chloritic phyllite which occurs interbanded with Keno Hill Quartzite at or near the top of the Earn Group. This unit is exposed in the Patterson Range and intermittently across the north slopes of Mount Haldane and Keno and Galena hills; it is referred to by Roots (1997) as unit MKv and by Murphy (1997b) as unit DMEv^{T}. The second candidate is Middle or Upper Devonian chloritic phyllite containing quartz granules (Unit DMv). In the Larsen Creek map area (116A/5, 6), Green and Roddick (1962) describe thin-bedded and phyllitic quartzite, graphitic and chloritic slate and phyllite within the Keno Hill Quartzite. In the central Lansing map area (105N), chlorite schist with relict feldspar phenocrysts (probable intermediate meta-volcanic tuff) occurs with Keno Hill Quartzite (C. Roots, pers. comm., 1999). Strata equivalent to the Keno Hill Quartzite have also been mapped in the Nahanni (105I; Gordey and Anderson, 1993) and Dawson (116B) map areas.

SUMMARY

MINERALIZATION

Volcanic-associated massive sulphide (VMS) deposits and prospects hosted by rocks of the **Yukon-Tanana Terrane** were recently discovered in the Finlayson Lake area of the Yukon. The deposits occur in distinct tectonic and stratigraphic settings at several stratigraphic levels in the terrane. Stratigraphically, from oldest to youngest, the main deposits are Fyre Lake, Kudz Ze Kayah and GP4F, Wolverine, and Ice.

- **Fyre Lake** has a resource of 8 200 000 million tonnes of 2.1% Cu and 0.73 g/t Au (GCNL, 1998), and is the stratigraphically lowest deposit. It is hosted by Devono-Mississippian rocks of the Grass Lakes succession (Murphy and Piercey, 1999b). The deposit (Foreman, 1998) includes two parallel zones of mineralization, East Kona and West Kona, separated by a reverse fault. East Kona mineralization consists of two massive to banded sulphide horizons 100 to 150 m thick. These horizons consist mainly of pyrite with lesser pyrrhotite and chalcopyrite, and local lenses of massive magnetite. The West Kona zone is 75 to 125 m (inferred) wide, with mineralization that changes laterally from magnetite, pyrite and chalcopyrite in a siliceous matrix, through massive pyrite and lesser chalcopyrite, to massive pyrrhotite with minor pyrite and chalcopyrite. The mineralization occurs close to a contact between chlorite schist and overlying carbonaceous phyllite (Blanchflower et al., 1997; Hunt and Murphy, 1998; Foreman, 1998). Chlorite schists that host the deposit have a distinct boninitic chemical signature that can be used to distinguish them from chlorite schists of similar appearance found elsewhere on the property (Sebert and Hunt, 1999).
- **Kudz Ze Kayah** has a resource of 13 000 000 tonnes of 5.5% Zn, 1% Cu, 1.3% Pb, 125 g/t Ag and 1.2 g/t Au, and GP4F has a resource of 1 500 000 tonnes of 6.4% Zn, 3.1% Pb, 0.1% Cu, 89.7 g/t Ag and 2.0 g/t Au (Cominco Ltd., 1998; Expatriate Resources Ltd., 2000a). These deposits occur stratigraphically above the unit hosting the Fyre Lake deposit in a thick complex of Mississippian felsic metatuffs or flows interlayered with minor mafic sills or flows and metasedimentary rocks (Schultze, 1996; Murphy, 1998). Host felsic metavolcanic rocks have a broadly alkalic arc affinity (Piercey et al., 1999). The KZK (ABM) deposit is roughly tabular and contains several lenses that are collectively up to 22.5 m thick (Expatriate Resources Ltd., 1999a). The deposit is unexposed but occurs in an area marked by polymetallic sulphide float, and anomalous stream sediment and soil geochemisty (Schultze, 1996). It is also characterized by coincident electromagnetic and magnetic anomalies (ibid). GP4F is a thin massive sulphide lens that occurs about 6 km southeast of KZK (Expatriate Resources Ltd., 2000a).
- **Wolverine** has a resource of 6 237 000 tonnes of 12.66% Zn, 1.33% Cu, 1.55% Pb, 370.9 g/t Ag and 1.76 g/t Au (Westmin Resources Limited, 1998), and is hosted by felsic metavolcanic and metasedimentary rocks of the Carboniferous Wolverine Lake succession that overlies the Grass Lakes succession (Murphy and Piercey, 1999a,b). Massive sulphide mineralization occurs at the contact between underlying feldspar-quartz-phyric rhyolitic metavolcaniclastic rocks and overlying aphyric metarhyolite, and is interlayered with black argillite (Tucker et al., 1997; Expatriate Resources Ltd., 1999a; Bradshaw et al., 2001). Hanging wall strata include magnetite ± barite iron formation. The mineralization is made up of two massive sulphide lenses 1 to 9.8 m thick separated by an area of semi-massive and stringer mineralization (Bradshaw et al., 2001). The sulphide lenses are made up of pyrite and sphalerite with lesser chalcopyrite, pyrrhotite, galena, tetrahedrite-tennantite and arsenopyrite (Tucker et al., 1997; Expatriate Resources Ltd., 1999a; Bradshaw et al., 2001). The surface expression of the Wolverine deposit is marked by a vegetation kill zone and coincident Cu-Pb-Zn ± Ba ± Ag ± Au soil geochemical anomalies (Hunt, 1999). The hanging wall magnetite iron formation is a marker horizon that forms regional magnetic anomalies; these anomalies can be used as an exploration guide (Tucker et al., 1997).
- **Ice** has a resource of 4 561 863 tonnes of 1.48% Cu (Expatriate Resources Ltd., 1999a). It occurs uppermost in the stratigraphy within rocks correlative to the Campbell Range succession. Host rocks are Upper Paleozoic mafic volcanic rocks with probable MORB signatures (Piercey et al., 1999) locally interlayered with mudstone and chert (Plint and Gordon, 1997; Pigage, 1997; Becker, 1998). The mineralization (Pigage, 1997; Becker, 1998) is made up of an upper massive sulphide horizon

and a lower stockwork sulphide zone. Generally, the massive sulphide horizon occurs at the contact between porphyritic basalt and overlying massive basalt. Stockwork mineralization occurs about 35 m below the massive sulphide horizon within brecciated basalt. The mineralization is made up dominantly of pyrite and chalcopyrite, with locally abundant bornite. The surface expression of the deposit is marked by a vegetation kill zone and a malachite stained gossan over an area of anomalous copper values in soils.

As well as underlying the Finlayson Lake area, the Yukon-Tanana Terrane also underlies large parts of west, central and southern Yukon, including Dawson, Glenlyon and Teslin-Rancheria (see Figs. 29 and 32):

- Restoring approximately 425 km of right lateral strike-slip movement (Roddick, 1967; Tempelman-Kluit, 1976; Mortensen, 1983; Gabrielse, 1991) on the Tintina Fault brings the massive-sulphide-rich Finlayson Lake area adjacent to the main body of the Yukon-Tanana Terrane west of **Dawson** (Fig. 29). Yukon-Tanana Terrane rocks in the Dawson area are known as the Nasina Assemblage and the Klondike Schist. The Late Devonian to mid-Mississippian Nasina Assemblage is similar to rocks in the Finlayson Lake district (Mortensen, 1990) and hosts several sulphide showings including Clip, Mickey, Mort and Holly. The Permian Klondike Schist also hosts base metal occurrences, including Matson Creek, Baldy (Bal), Pub, Bronson and Floc.
- The Yukon-Tanana Terrane and correlative strata occur in south-central Yukon in the **Teslin-Rancheria** area and adjacent northern British Columbia (Figs. 2, 32; cf. Wheeler et al., 1988; Mortensen, 1992; Gordey and Makepeace, 1999). These rocks host several VMS prospects including Mor, Cabin Creek, Caribou Lake, Bar and Iron Creek.
- Yukon-Tanana Terrane correlative rocks that host massive sulphide mineralization have recently been mapped in the **Glenlyon** area (Fig. 32; Colpron, 1999a; Colpron and Reinecke, 2000).

The Yukon-Tanana Terrane extends westward from the Yukon and underlies a large part of east-central Alaska (see Fig. 2; Mortensen, 1992a; Lange et al., 1993; Dusel-Bacon et al., 1998). Devono-Mississippian rocks of the Yukon-Tanana Terrane in Alaska, regarded as coeval with those in the Finlayson Lake district, host VMS deposits and occurrences in a 150-km-long-belt that includes the Delta, Trident Glacier and Bonnifield districts (Table 5; Lange et al., 1993; Newberry et al., 1997).

- The **Delta** district hosts at least 35 massive sulphide occurrences generally in rhyolitic metavolcaniclastic units (Lange et al., 1993; Newberry et al., 1997).
- The **Trident Glacier** district occurs about 100 km northwest of the Delta district and contains similar but smaller massive sulphide deposits than those in the Delta district (Lange et al., 1993).
- The **Bonnifield** district occurs about 50 km northwest of the Trident Glacier district and contains at least 26 VMS prospects (Newberry et al., 1997), including the Dry Creek prospect where mineralization occurs at a volcanic to sedimentary transition (Atna Resources Ltd., 1999).

Strata coeval, and possible correlative, with those of the Yukon-Tanana Terrane underlie parts of eastern Yukon in the **North American miogeocline** (Figs. 1 and 2; cf. Gordey and Makepeace, 1999). Devono-Mississippian rocks of the miogeocline, coeval with those in the Finlayson Lake district, host VMS deposits in the Pelly-Cassiar Platform and Selwyn Basin (Fig. 32; cf. Morin, 1977; Turner and Abbott, 1990; Holbeck and Wilson, 1998; Gibson et al., 1999).

- Within the **Pelly-Cassiar Platform,** VMS mineralization occurs in an 80-km-long belt of Devono-Mississippian volcanic rocks and includes the MM, Chzerpnough (Fire), Bnob (Ice), Tree and Mamu prospects, and the Wolf deposit (Fig. 32; cf. Gordey, 1978, 1979; Mortensen 1979, 1981). The Wolf deposit occurs at the southern end of the belt within a sequence of tuffs and trachyte flows, sills and/or dykes proximal to a syenite sill, and contains an inferred resource of 4.1 million tonnes with grades of 6.2% Zn, 1.8% Pb and 84 g/t Ag (Gibson et al., 1999).
- Within the **Selwyn Basin,** VMS mineralization occurs in the north-central part in probable early Mississippian metavolcanic and metasedimentary rocks. The **Marg** deposit is the major known occurrence, and is located in a thrust panel between the Robert Service and Tombstone thrust faults (Abbott, 1990a,b). It contains an inferred resource of 5 527 002 tonnes grading 1.76% Cu, 2.46% Pb, 4.60% Zn, 62.7 g/t Ag and 0.98 g/t Au (NDU Resources Ltd., 1996). It is hosted by deformed carbonaceous siliceous phyllite and lenses of quartz-muscovite and quartz-chlorite phyllite (Abbott, 1990a,b; Turner and Abbott, 1990; Gish, 1998).

EXPLORATION POTENTIAL

The following features point to significant VMS exploration potential in the Yukon-Tanana Terrane:

- Discovery of Kudz Ze Kayah and Wolverine was followed by a period of intense exploration activity in the Finlayson Lake district and other areas of the Yukon-Tanana Terrane, and in coeval strata. Many VMS prospects discovered during this time have not been fully explored.
- Newly defined VMS deposits are comparable in size and grade to the average Canadian VMS deposit (see Table 1).
- In the Yukon-Tanana Terrane VMS mineralization is known to occur in strata from Late Devonian to Permian in age, thus there are several prospective horizons as shown in Table 5.
- VMS deposits in general seem to occur in clusters with spacing primarily controlled by the arrangement of hydrothermal convection cells (Franklin et al., 1981). For example, in Cyprus individual deposits spaced 2 to 4.5 km apart occur in groups of 7.6 to 12.5 km apart. In the Yukon a cluster of deposits has been discovered in only one area (KZK, GP4F, Fault Creek zone), thus the areas surrounding Fyre Lake, Wolverine, Ice, Wolf and Marg could potentially contain further VMS deposits.

Table 5. Age of VMS mineralization host rocks in the Yukon-Tanana Terrane. See descriptions of individual deposits and prospects in the main text for more detail and reference information. Locations are shown on Figures 1, 2, 4, 29 and 32.

Age of host rocks	Host rocks	VMS deposits and prospects
Devono-Mississippian	Finlayson Lake area: Grass Lakes succession	Fyre Lake, KZK, GP4F, Fault Creek zone, Pack (Pak), Blueline, Pneumonia (Mony), Akhurst (Expo), Ant (Hat Trick), Goal-Net, Red Line, Cobb, League, Nad
Late Devonian to mid Mississippian	Dawson area: Nasina Assemblage	Clip, Mickey, Mort, Holly, Pup, Fan, Coal, Swde, Bruin
Devonian	Alaska: sub-terranes of the Yukon-Tanana Terrane	Delta, Bonnifield, Trident Glacier and other districts
Carboniferous	Finlayson Lake area: Wolverine Lake succession	Wolverine
Pennsylvanian to Permian	Finlayson Lake area: Campbell Range succession	Ice, Money (Julia)
Permian	Dawson area: Klondike Schist	Matson Creek, Baldy (Bal), Pub, Bronson, Floc

REFERENCES

Abbott, G., 1990a. Geological map of Mt. Westman map area (106D/1). Open File 1990-1. Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada.

Abbott, G., 1990b. Preliminary results or the stratigraphy and structure of the Mt. Westman map area, central Yukon. *In:* Current Research, Part E, Geological Survey of Canada, Paper 90-1E, p. 15-22.

Asher, R.R., 1970. Geochemistry & geology, Boundary area, Fortymile district, Eagle A-1 quadrangle, Alaska. Division of Mines and Geology, Department of Natural Resources, State of Alaska, Geochemical Report No. 23, 35 p.

Atna Resources Ltd., 1999. Atna Resource Ltd. website. Website address http://www.atna.com.

Baknes, M., 1997a. Money. *In:* Massive Sulphide Deposits in the Yukon-Tanana and Adjacent Terranes. *In:* Yukon Exploration and Geology, 1996; Yukon Geology Program, p. 38-40.

Baknes, M.E., 1997b. Geological and diamond drilling report on the Money property, Yukon Territory, NTS 105H/5 and 105G/8. Assessment Report 093649 written by Equity Engineering Ltd. for Atna Resources Ltd.

Baknes, M.E., 1996. Geological, geophysical and diamond drilling report on the Argus property, Yukon Territory, NTS 105G/12. Assessment Report 093582 written by Equity Engineering Ltd. for Atna Resources Ltd.

Baknes, M.E., 1995. 1994 Summary report on the Pak claims, NTS 105G/7, Watson Lake Mining District. Assessment Report 093278 written for Atna Resources Ltd.

Baknes, M.E., 1994. 1993 Summary report on the Pak claims, NTS 105G/7, Watson Lake Mining District. Assessment Report 093203 written for Atna Resources Ltd.

Baknes, M. E. and Weber, J.S., 1996. 1995 summary report on the Foot 1-80, 83-174, 180-231, Kink 3, Toe 1-16, 26 claims, Watson Lake Mining District. Assessment Report 093404 written for Westmin Resources Limited by Equity Engineering Ltd., 4 volumes.

Bannister, V.L., 1997a. 1997 Assessment Report, Expo/Xpo/Pop/Fly (including areas of Base, Ball, Bat, Home & Run blocks) properties, geologic mapping, prospecting, diamond drilling, and geochemical sampling, Watson Lake Mining District, Yukon, Pelly Mountains area, NTS 105G/1 & 8. Assessment Report 093816 written for Cominco Ltd.

Bannister, V.L., 1997b. 1996 Assessment Report, Cobb property, geological mapping/prospecting and geochemistry, Watson Lake Mining District, Yukon, Pelly Mountains area, NTS 105G/7. Assessment Report 093713 written for Cominco Ltd.

Barrie, C.T. and Hannington, M.D., 1997. Classification of VMS deposits based on host rock composition. *In:* Volcanic-associated massive sulphide deposits: processes and examples in modern and ancient settings, a volume to accompany a GAC-MDD-SEG co-sponsored short course, C.T. Barrie and M.D. Hannington (eds.), Carleton University, Ottawa, Ontario, May 17-18, 1997, p. 1-12.

Becker, T.C., 1998. Assessment Report describing geological mapping, prospecting, soil geochemistry, and diamond drilling on the Ice property in the Watson Lake Mining District, Yukon Territory. Assessment Report 093869 written for Expatriate Resources Ltd.

Becker, T.C., 1997. Geological mapping, prospecting, soil geochemistry and airborne geophysical surveys on the Ice property. Assessment Report 093839 written for Expatriate Resources Ltd.

Blanchflower, J.D., 1997. Exploration Report on the Fyre Lake property, Watson Lake Mining District, Yukon Territory, Canada. Internal Report for Columbia Gold Mines Ltd.,

Blanchflower, D. and Deighton, J., 1996. Linecutting, prospecting, geochemical and geophysical report on the Fyre Lake property. Watson Lake Mining District, Yukon Territory, Canada. Assessment Report 93569 written for Columbia Gold Mines Ltd.

Blanchflower, D., Deighton, J. and Foreman, I., 1997. The Fyre Lake deposit: A new copper-cobalt-gold VMS discovery. *In:* Yukon Exploration and Geology, 1996; Yukon Geology Program, p. 46-52.

Blusson, S., 1976. Selwyn Basin, Yukon and District of Mackenzie. *In:* Report of Activities, Part A, Geological Survey of Canada, Paper 76-1A, p. 131-132.

Bond, J.D., Murphy, D.C., Colpron, M., Gordey, S.P., Plouffe, A., Roots, C.F., Lipovsky, P.S, Stronghill, G. and Abbott, J.G., 2002. Digital Compilation of Bedrock Geology and Till Geochemistry, Northern Finlayson Lake Map Area, Southeastern Yukon (105G). Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Open File 2002-7(D). Also available as Geological Survey of Canada, Open File 4234.

Bradshaw, G.D., Tucker, T.L., Peter, J.M., Paradis, S. and Rowins, S.M., 2001. Geology of the Wolverine polymetallic volcanic-hosted massive sulphide deposit, Finlayson Lake district, Yukon Territory, Canada. *In:* Yukon Exploration and Geology 2001, D.S. Emond and L.H. Weston (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs, Canada, p. 269-287.

Brown, A.V. and Jenner, G.A., 1989. Geological setting, petrology and chemistry of Cambrian boninite and low-Ti tholeiite lavas in western Tasmania. *In:* Boninites, Chapter 9, A.J. Crawford (ed.), Unwin Hyman Inc., 465 p.

Burgert, A., 1997a. Geological mapping, prospecting, soil geochemistry, airborne geophysics and claim surveys on the Shutout property, NTS 105G/1 in the Watson Lake Mining District, Yukon Territory. Assessment Report 093673 written for Expatriate Resources Ltd.

Burke, M., 1999. Yukon mining and exploration overview; Exploration; Base Metals, 1998. *In:* Yukon Exploration and Geology, 1998. Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs, Canada, p. 20.

Burke, M., 1998. Yukon mining and exploration overview; Exploration; Base Metals, 1997. *In:* Yukon Exploration and Geology, 1997. Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs, Canada, p. 14-25.

Cameron, W.E., 1985. Petrology and origin of primitive lavas from the Troodos ophiolite, Cyprus. Contributions to Mineralogy and Petrology, 89, p. 256-62.

Campbell, I.H., Franklin, J.M., Gorton, M.P., Hart, T.R. and Scott, S.D., 1981. The role of subvolcanic sills in the generation of massive sulphide deposits. Economic Geology, vol. 76, p. 2248-2253.

Carne, R.C., 1999. Report on excavator trenching on the Top property in the Dawson mining district, Yukon Territory. Assessment Report 093952 written for Nordac Resources Ltd.

Carne, R.C., 1996a. Geochemical survey report on the Fresno property, Dawson Mining District, Yukon Territory. Assessment Report 093533 written for Nordac Resources Ltd.

Carne, R.C., 1996b. Geochemical and geophysical survey report on the River property, Dawson Mining District, Yukon Territory. Assessment Report 093534 written for Nordac Resources Ltd.

Carne, R.C., 1996c. Geochemical survey report on the Top property, Dawson Mining District, Yukon Territory. Assessment Report 093535 written for Nordac Resources Ltd.

Carne, R.C., 1993a. Summary report on 1992 exploration, Matson Creek property, Dawson Mining District. Assessment Report 093099 written for YGC Resources Ltd.

Carne, R.C., 1993b. Summary report on 1992 exploration, BAL and PUB Claims, Dawson Mining District. Assessment Report 093098 written for YGC Resources Ltd.

Carne, R.C., 1991a. Summary report on 1991 exploration, Mickey Creek Property, MIC Claims, Dawson Mining District. Assessment Report 092997 written by for YGC Resources Ltd.

Carne, R.C., 1991b. Summary report on 1991 exploration, MORT Claims, Dawson Mining District. Assessment Report 092998 written by for YGC Resources Ltd.

Carne, R.C., 1991c. Summary Report on 1991 prospecting, CLI claims, Dawson Mining District. Assessment Report 092999 for YGC Resources Ltd.

Carne, R.C., 1991d. Summary report on 1990 exploration, PUB Claims, Dawson Mining District. Assessment Report 092957 written for YGC Resources Ltd.

Carne, R.C., 1991e. Summary report on 1991 exploration, Matson Creek property, Dawson Mining District. Assessment Report 093000 written for YGC Resources Ltd.

Carne, R.C., 1990. Summary Report on 1990 exploration, Lynx claims, Watson Lake Mining District. Assessment Report 092961 written for YGC Resources Ltd.

Cathro, R.J., 1988. Summary report, 1988 field program, Marg property, Yukon. Private company report for Archer, Cathro and Associates (1981) Limited.

Chronic, F., 1979. Geology of the Guano-Guayes rare earth element-bearing skarn property, Pelly Mountains, Yukon Territory. M. Sc. Thesis, the University of British Columbia, Vancouver, British Columbia, 122 p.

Colpron, M. and Reinecke, M., 2000. Glenlyon project: coherent stratigraphic succession of Yukon-Tanana Terrane in the Little Salmon Range, and its potential for volcanic-hosted massive sulphide deposits, central Yukon. *In:* Yukon Exploration and Geology 1999, D.S. Emond and L.H. Weston (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 87-100.

Colpron, M., 1999a. Glenlyon project: preliminary stratigraphy and structure of Yukon-Tanana Terrane, Little Kalzas area, central Yukon (105L/13). *In:* Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs, Canada, p. 63-71.

Colpron, M., 1999b. A new mineral occurrence in Yukon-Tanana Terrane near Little Salmon Lake (105L/2), central Yukon. *In:* Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs, Canada, p. 255-258.

Cominco Ltd., 1998. Annual Report for 1998.

Crawford, A.J., 1989. Boninites. Unwin Hyman, 465 p.

Crawford, A.J., Falloon, T.J. and Green, D.H., 1989. Classification, petrogenesis and tectonic setting of boninites. *In:* Boninites, A.J. Crawford (ed.), Unwin Hyman, p. 1049.

Creaser, R.A., Erdmer, P., Grant, S.L. and Stevens, R.A., 1995. Tectonic identity of metasedimentary strata from the Teslin Tectonic Zone, SE Yukon: geochemical and Nd isotopic constraints. *In:* Lithoprobe, Slave-Northern Cordillera Lithospheric Evolution (SNORCLE), Report of 1995 Transect Meeting, April 8-9, 1995, Lithoprobe Report no. 44, p. 51-55.

Daubeny, P., Wilson, R.G. and Holbek, P., 1998. 1998 project report on the Fire and Tree property. Assessment Report 094001 written for Atna Resources Ltd.

Davidson, G.S., 1997. Assessment Report on the Primo claims, McPherson Lake area. Assessment Report 093724 written for P. Risby.

Deighton, J. and Foreman I.J., 1997. Diamond drilling and GPS grid surveying report on the Fyre Lake property, Watson Lake Mining District, Yukon Territory, Canada. Assessment Report 093778 written for Columbia Gold Mines Ltd.

Department of Mines and Technical Surveys, 1961a. Finlayson Lake, Yukon Territory, sheet 105G. Geophysics Paper/Map 7006G, scale one inch to four miles. (1:253 440).

Department of Mines and Technical Surveys, 1961b. Frances Lake, Yukon Territory, sheet 105H. Geophysics Paper/Map 7007G, scale one inch to four miles (1:253 440).

Department of Mines and Technical Surveys, 1961c. One inch to 1 mile (1:63 360) scale geophysical maps for NTS map sheets 105G/1 to 16. Geological Survey of Canada, geophysics papers 1360 to 1363, 1376 to 1379, 1388 to 1391, 1404 to 1407, 16 maps.

Dickie, J.R., 1997. Geology and Mineralization of the Fire and Ice VMS occurrences. Eagle Plains Resources Internal Report, 11 p.

Dickie, J.R., 1996a. Geological Assessment Report for the Fire 1-12 mineral claims, Watson Lake Mining District, Yukon Territory, NTS 105 F-9. Assessment Report 093607 written for Eagle Plains Limited.

Dickie, J.R., 1996b. Geological Assessment Report for the Ice 1-10 mineral claims, Watson Lake Mining District, Yukon Territory. Assessment Report 093608 written for Eagle Plains Resources Limited.

DiLabio, R.N.W., 1989. Terrain geochemistry in Canada. *In:* R.J. Fulton (ed.), Quaternary Geology of Canada and Greenland, Chapter 10. Geological Survey of Canada, Geology of Canada, no. 1. (Also available as Geological Society of America, The Geology of North America, vol. K-1).

Doherty, A., 1997. Mamu-Bravo-Kulan claims: a VHMS exploration target based on geochemical and geophysical anomalies in Mississippian volcanics within Cassiar Platform, NTS 105-F/7,8,9, & 10. *In:* Yukon Exploration and Geology, 1996; Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs, Canada, p. 56-61.

Downie, C.C., (2000). Geological report for the Fire(Chzerpnough) and Ice(Bnob) properties. Internal company report for Eagle Plains Resources Ltd.

Duk-Rodkin, A., 1999. Glacial limits map of Yukon Territory. Geological Survey of Canada, Open File 3694, Indian and Northern Affairs Canada Geoscience Map 1999-2, scale 1:1 000 000.

Duk-Rodkin, A., 1996. Surficial geology, Dawson, Yukon Territory. Geological Survey of Canada, Open File 3288, scale 1:250 000.

Dunn, C.E., 1995, Mineral exploration beneath temperate forests: the information supplied by trees, Exploration Mining Geology Journal, v. 4, p. 197-204.

Dusel-Bacon, C., Bressler, J.R., Takaoka, H., Mortensen, J.K., Oliver, D.H., Leventhal, J.S., Newberry, R.J. and Bundtzen, T.K., 1998. Stratiform zinc-lead mineralization in Nasina Assemblage rocks of the Yukon-Tanana Upland in east-central Alaska. USGS Open file report 98-340, 20p. Also available from http://caldera.wr.usgs.gov/syngenms/OF98-340.html

Eagle Plains Resources Ltd., 2000. Website, http://www.EaglePlains.British Columbia.ca

Eagle Plains Resources Ltd., 1997. Miner River/Eagle Plains sign letter of agreement with Atna on "Fire" and "Ice" properties, Yukon Territory. News Release, September 18

Eaton, W.D., 1997a. Assessment Report describing geological mapping, soil geochemistry, geophysical surveys and diamond drilling at the Slap Shot property on NTS 105G/7 in the Watson Lake Mining District, Yukon Territory. Assessment Report 093587 written for Expatriate Resources Ltd.

Eaton, W.D., 1997b. Assessment Report describing geological mapping, soil sampling, geophysical surveys and diamond drilling at the Hat Trick property on NTS 105G/2 & 7 in the Watson Lake Mining District, Yukon Territory. Assessment Report 093620 written for Expatriate Resources Ltd.

Eaton, W.D., 1997c. Assessment Report describing geological mapping, soil sampling, geophysical surveys and diamond drilling at the League property on NTS 105G/10 in the Watson Lake Mining District, Yukon Territory. Assessment Report 093571 written for Expatriate Resources Ltd.

Eaton, D., 1996. The Ice Property. Talk given at the Geological Association of Canada volcanogenic massive sulphide deposits workshop held at Simon Fraser University downtown campus, Vancouver, British Columbia, November 14, 1996.

Eaton, D. and Pigage, L., 1997. Geological mapping, prospecting, soil geochemistry, geophysical surveys and diamond drilling on the Ice property. Assessment Report 093718 written for Archer, Cathro and Associates (1981) Limited.

Evensen, N.M., Hamilton, P.J. and O'Nions, R.K., 1978. Rare earth abundances in chondritic meteorites. Geochemica Cosmochimica Acta, vol. 42, p. 1199-1212.

Expatriate Resources Ltd., 2001. Finlayson project exploration outlook. Expatriate Resources Ltd. website. http:\\www.expatriateresources.com/Finlayson_exploration_outlook.html

Expatriate Resources Ltd., 2000a. Finlayson Development Plan. Promotional handouts from presentations given to government agencies and First Nations, Vancouver, British Columbia Oct 12th and Whitehorse, Yukon, October 13-18th.

Expatriate Resources Ltd., 2000b. News Release, Oct, 11th.

Expatriate Resources Ltd., 2000c. Expatriate receives Wolverine results. News Release, June 20th.

Expatriate Resources Ltd., 2000d. Expatriate receives Finlayson results. News Release, June 27th.

Expatriate Resources Ltd., 2000e. Hatch completes pre feasibility study for Finlayson project. News Release, November 8th.

Expatriate Resources Ltd., 2000f. Expatriate Resources updates Yukon property progress. News Release, July 17th.

Expatriate Resources Ltd., 1999a. Expatriate Resources Ltd. Website (May 11, 1999). Website address http://www.expatriateresources.com

Expatriate Resources Ltd., 1999b. 1999 Annual Report.

Expatriate Resources Ltd., 1998. Expatriate Resources Ltd. Website (February 1998). Website address http://www.expatriateresources.com

Fairfield Minerals Ltd., 2001. Fairfield Minerals Ltd. Website. Website address http://www.fairfieldminerals.com

Fedikow, M.A.F. and Dunn, C.E., 1996. The geochemistry of vegetation growing over the deeply buried Chisel north Zn-rich massive sulphide deposit, Snow Lake area. *In:* G.F. Bonham-Carter, A.G. Galley and G.E.M. Hall (eds.), EXTECH I: A multidisciplinary approach to massive sulphide research in the Rusty Lake-Snow lake greenstone belts, Manitoba, Geological Survey of Canada, Bulletin 426, p. 225-255.

Foreman, I., 1998. The Fyre Lake project 1997: Geology and mineralization of the Kona massive sulphide deposit. *In:* Yukon Exploration and Geology, 1997, Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs, Canada, p. 105-114.

Foster, H.L., 1992. Geologic map of the eastern Yukon-Tanana region, Alaska. United States Geological Survey, Open File Report 92-313, 26 p.

Franklin, J.M., 1996. Volcanic-associated massive sulphide base metals. *In:* Geology of Canadian Mineral Deposit Types, O.R. Eckstrand, W.D. Sinclair and R.I. Thorpe, (eds.); Geological Survey of Canada, Geology of Canada, no. 8, p. 158-183. (part of the DNAG series).

Franklin, J.M., Lydon, J.W. and Sangster, D.F., 1981. Volcanic-associated massive sulphide deposits. *In:* B.J. Skinner (ed.), Economic Geology Seventy-fifth Anniversary Volume 1905-1980, p. 485-627.

Franzen, J.P., 1997. Assessment of mineral reserves: Marg Zn-Cu-Pb-Au-Ag property. Unpublished company report of NDU Resources Ltd., 23 p.

Friske, P.W.B., Hornbrook, E.H.W., Lynch, J.J., McCurdy, M.W., Gross, H., Galletta, A.C. and Durham, C.C., 1990. Regional stream sediment and water geochemical data, west-central Yukon (NTS 116B, parts of 116C, 116F, 116G). Geological Survey of Canada, Open File 2365.

Fritz, W.H., Cecile, M.P., Norford, B.S., Morrow, D. and Geldsetzer, H.H.J., 1991. Cambrian to Middle Devonian assemblages. *In:* Geology of the Cordilleran Orogen in Canada, H. Gabrielse and C.J. Yorath (eds.); Geological Survey of Canada, Geology of Canada, no. 4., p. 151-218.

Gabrielse, H. (Comp), 1991. Structural Styles, Chapter 17. *In:* Geology of the Cordilleran Orogen in Canada, H. Gabrielse and C.J. Yorath (eds.); Geological Survey of Canada, Geology of Canada, no. 4., p. 571-675.

Gabrielse, H., 1967. Tectonic evolution of the northern Canadian Cordillera. Canadian Journal of Earth Sciences, vol. 4, p. 271-298.

Gabrielse, H. and Yorath, C.J., 1991. Tectonic synthesis, Chapter 18. *In:* Geology of the Cordilleran Orogen in Canada, H. Gabrielse and C.J. Yorath (eds.); Geological Survey of Canada, Geology of Canada, no. 4., p. 679-705.

Gale, D.F., Terry, D.A. and Duke, N.A., 1998. 1997 Assessment Report describing geological and geochemical surveys on the Pak 1 to 70 claims, Finlayson lake area, Yukon Territory. Assessment Report 093780 written for Westmin Resources Limited.

Galley, A.G., 1996. Geochemical characteristics of subvolcanic intrusions associated with Precambrian massive sulphide deposits. *In:* Trace Element Geochemistry of Volcanic Rocks: Applications for Massive Sulphide Exploration, D.A. Wyman (ed.), Geological Association of Canada, Short Course Notes Volume 12, p. 239-278.

GCNL (George Cross News Letter), 1998. Columbia Gold reports resource for Fyre Lake.

Gehrels, G.E., McClelland, W.C., Sampson, S.D. and Patchett, P.J., 1992. Geology of the western flank of the Coast Mountains between Cape Fanshaw and Taku inlet, southeastern Alaska. Tectonics, vol. 11, p. 567-585.

Geological Survey of Canada, 1998. Airborne geophysical survey, Grass Lakes area (NTS 105G/2, 7, 8). Geological Survey of Canada Open File 3552, 1:150,000 scale.

Geological Survey of Canada, 1978. Regional stream sediment and water geochemical reconnaissance data, 116 B, parts of 116C, 116F & 116G. Geological Survey of Canada, Open File 2365.

Geological Survey of Canada, 1963. Aeromagnetic map of Finlayson Lake, Yukon Territory, sheet 105G. Geological Survey of Canada, Geophysics Paper/Map 7006 G, scale: one inch to four miles.

Gibson, A.M., Holbek, P.M. and Wilson, R.G., 1999. The Wolf property - 1998 update: volcanogenic massive sulphides hosted by rift-related, alkaline, felsic volcanic rocks, Pelly Mountains, Yukon. *In:* Yukon Exploration and Geology, 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 237-242.

Gish, R. F., 1998. Report on 1997 trenching and diamond drilling on the Marg project. Assessment Report 093832 written for NDU Resources Ltd.

Gleeson, C.F., 1965a. Heavy metal content of stream and spring waters, Rackla River, Yukon Territory. Geological Survey of Canada, Map 24-1964.

Gleeson, C.F., 1965b. Heavy metal content of stream and spring waters, Rackla River, Yukon Territory. Geological Survey of Canada, Map 25-1964.

Godwin, C.I. and Sinclair, A.I., 1982. Average lead isotope growth curves for shale-hosted zinc-lead deposits, Canadian Cordillera. Economic Geology, vol. 7, p. 675-690.

Gordey, S.P., 1995. Structure and terrane relationships of Cassiar and Kootenay (Yukon-Tanana) Terranes, Teslin map area, southern Yukon Territory. *In:* Current Research 1995-A, Geological Survey of Canada, p. 135-140.

Gordey, S.P., 1990. Geology and mineral potential, Tiny Island Lake map area, Yukon. *In:* Current Research, Part E, Geological Survey of Canada, Paper 90-1E, p. 23-29.

Gordey, S.P., 1981. Stratigraphy, structure and tectonic evolution of southern Pelly Mountains in the Indigo Lake area, Yukon Territory. Geological Survey of Canada, Bulletin 318, 44 p.

Gordey, S.P., 1979. Stratigraphy of southern Selwyn Basin in the Summit Lake area, Yukon Territory and Northwest Territories. Geological Survey of Canada, Paper 79-1A, p. 13-16.

Gordey, S.P., 1978. Stratigraphy and structure of the Summit Lake area, Yukon Territory and District of Mackenzie. Geological Survey of Canada, Paper 78-1A, p. 43-48.

Gordey, S.P., 1977. Stratigraphy, structure and tectonic evolution of the southern Pelly Mountains in the Indigo Lake area, Yukon Territory. Ph.D. thesis, Queen's University, Kingston, Ontario, 200 p.

Gordey, S.P. and Makepeace, A.J., 1999. Yukon Digital Geology. Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Open File 1999-1(D), two CDs. Also available as Geological Survey of Canada, Open File D3826.

Gordey, S.P. and Anderson, R.G., 1993. Evolution of the northern cordilleran miogeocline, Nahanni map area (105I), Yukon and Northwest Territories. Geological Survey of Canada, Memoir 428, 214 p.

Gordey, S.P. and Tempelman-Kluit, D.J., 1976. Stratigraphic and structural studies in the Pelly Mountains, Yukon Territory. Geological Survey of Canada, Paper 76-1B, p. 1-5.

Goodfellow, W.D.; Cecile, M.P. and Leybourne, M.I., 1995. Geochemistry, petrogenesis, and tectonic setting of lower Paleozoic alkalic and potassic volcanic rocks, Northern Canadian Cordilleran miogeocline. Canadian Journal of Earth Sciences, No. 32, p. 1236-1254.

Grayd Resources Corporation, 2001. Website http://www.grayd.com

Green, L.H. and Roddick, J.A., 1962. Geology, Larsen Creek, Yukon Territory. Geological Survey of Canada map 1283A. *In:* Geology of Nash Creek, and Dawson map-areas, Yukon Territory, L.H. Green (ed.), Geological Survey of Canada, Memoir 364.

Harman, A.G., 1996. Prospecting and geochemical soil sampling on the Ty claims, Finlayson Lake area, Yukon Territory, NTS 105G/1, Watson Lake Mining District. Forms part of Assessment Report 093430.

Haverslew, R.E., 1978. Borden Creek prospect, Bord Claims. Assessment Report 090437 written for Ocean Home Exploration Co. Ltd. (open).

Holbeck, P.M. and Wilson, R.G., 1998. The Wolf discovery: A kuroko-style volcanogenic massive sulphide deposit hosted by rift-related, alkaline felsic volcanic rocks. *In:* Yukon Exploration and Geology, 1997, Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 115-120.

Holroyd, R.W., 1997. Geophysical surveys on the Goal-Net property, Yukon Territory. Assessment Report 093550 written for Cominco Ltd.

Holroyd, R.W., 1996. Combined helicopter-borne magnetic and electromagnetic survey on the Cobb claims, Pelly Mountain project, Yukon Territory. Assessment Report 093429 written for Cominco Ltd.

Holroyd, R.W., 1993. 1992 report on geophysical surveys, Wolf property, Watson Lake Mining District, Yukon. Assessment Report 093084 written for Cominco Ltd.

Hornbrook, E.H.W. and Friske, P.W.B., 1988. Regional stream sediment and water geochemical data, southeastern Yukon, Geological Survey of Canada Open File 1648.

Hornbrook, E.H.W. and Friske, P.W.B., 1986. Regional stream sediment and water geochemical reconnaissance data Yukon (NTS 115N, east half; 115O). Geological Survey of Canada Open File 1364.

Hughes, O.L., 1987. Quaternary geology. *In:* Guidebook to Quaternary Research in Yukon, S.R. Morison and C.A.S. Smith (eds.), XII INQUA Congress, Ottawa, Canada; National Research Council of Canada, Ottawa, p. 12-16.

Hughes, O.L., Campbell, R.B., Muller, J. and Wheeler, J.D., 1969. Glacial limits and flow patterns, Yukon Territory south of 65°N latitude. Geological Survey of Canada, Paper 68-34, 9 p.

Hulstein, R., 1994. Assessment Report for the Argus property. Assessment Report 093194 written for Kennecott Canada Inc.

Hunt, J.A., 1999a. Preliminary stratigraphy and distribution of Devono-Mississippian massive sulphide-bearing volcanic rocks in the Mount Vermilion (Wolf) area, Pelly Mountains (105G/5 and G/6), southeast Yukon. *In:* Yukon Exploration and Geology, 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 73-89.

Hunt J.A., 1999b. Preliminary results from water sampling in the PCP volcanic belt, southeastern Yukon. *In:* Yukon Exploration and Geology, 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 167-177.

Hunt, J.A., 1999c. Finlayson Lake district, Yukon: Canada's newest VMS camp. *In:* C.J. Stanley et al. (eds.), Mineral Deposits: Processes to Processing, volume 1, Balkema, Rotterdam, p. 535-537.

Hunt, J.A., 1998a. The setting of volcanogenic massive sulphide deposits in the Finlayson Lake district. *In:* Yukon Exploration and Geology, 1997, Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 99-104

Hunt, J.A., 1998b. Recent discoveries of volcanic-associated massive sulphide deposits in the Yukon. CIM Bulletin, v. 90, # 1017, Feb. 1998, p. 56-65.

Hunt, J.A., 1998c. Preliminary geology of the Mount Vermilion area, Pelly-Cassiar Platform, Yukon Territory, 1:25,000 scale map (parts of 105G/5 & 6). Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Open File 1998-5.

Hunt, J.A., 1997. Massive sulphide deposits in the Yukon-Tanana and adjacent terranes. *In:* Yukon Exploration and Geology, 1996, Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Yukon Geology Program, p. 35-45.

Hunt, J.A. and Murphy, D.M., 1998. A note on preliminary mapping in the Fire Lake area. *In:* Yukon Exploration and Geology 1997, Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 59-68.

Hunt, J.A., Dunn, C.E., Timmerman, J.R.M. and Zantvoort, W.G., 1997, Biogeochemical prospecting in the Yukon-Tanana Terrane, Yukon Territory. *In:* Yukon Exploration and Geology 1996, Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 74-91.

Jackisch, I., 1995a. Geophysical surveys on the Expo/Mony claims of the Pelly Mtn properties, Watson Lake Mining District, Yukon, NTS 105G/1, 8, 105H/5. Assessment Report 093427 written for Cominco Ltd.

Jackson, L.E. Jr., 1994. Terrane inventory and Quaternary history of the Pelly River area, Yukon Territory. Geological Survey of Canada Memoir 437, 41p, 16 maps.

Johnston, S.T. and Mortensen, J.K., 1994. Regional setting of porphyry Cu-Mo deposits and volcanogenic massive sulphide deposit, and mesothermal gold deposits in the YTT, Yukon. *In:* J.L. Jambor (editor), Abstracts and Proceedings of the district 6 Canadian Institute of Mining 1994 Annual General Meeting, p. 30-34.

Kallock, P., 1995. Geological, rock and soil geochemical surveys and trenching, Money 1-46 mineral claims, Watson Lake Mining District, Yukon Territory, NTS 105H/5 and 105G/8. Assessment Report 093424 written for Atna Resources Ltd.

Kallock, P., 1996. Geological, rock and soil geochemical survey Argus mineral claims, Watson Lake Mining District, Yukon Territory, NTS 105G/12. Assessment Report 093469 written for Atna Resources Ltd.

Keyser, H.J., 1996. Report on the 1996 diamond drilling program on the Eldorado property, Watson Lake Mining District, Yukon, NTS 105G\12. Assessment Report 093552 written for Mar-West Resources Ltd.

Kimball, A.L., Still, J.C. and Rataj, J.L., 1984. Mineral deposits and occurrences in the Tracy Arm-Fords Terror wilderness study area and vicinity, Alaska. United States Geological Survey, Bulletin 1525-E, p. 105-210.

Kreft, B., 1997a. Geological Assessment Report for the Bnob mineral property. Assessment Report 093793 written for Eagle Plains Resources and Miner River Resources.

Kreft, B., 1997b. Geological Assessment Report for the Chzerpnough mineral property. Assessment Report 093794 written for Eagle Plains Resources and Miner River Resources.

Lange, I.M., Nokelberg, W.J., Newkirk, S.R., Aleinikoff, J.N, Church, S.E. and Krouse, H.R., 1993. Devonian volcanogenic massive sulfide deposits and occurrences, southern YTT, eastern Alaska Range, Alaska. Economic Geology, vol. 88, p. 344-376.

Large, R., Doyle, M., Raymond, O., Cooke, D., Jones, A. and Heasman, L., 1996. Evaluation of the role of Cambrian granites in the genesis of world class VHMS deposits in Tasmania. Ore Geology Reviews, vol. 10, p. 215-230.

Leitch, C.H.B., 1998. Petrographic report on 194 samples from volcanic-associated massive sulphide deposits in Yukon. Unpublished report for the VMS project, included here as Appendix VI-3.

Leitch, C.H.B., 1990. Ore textures in Turkish volcanogenic massive sulphide deposits in light of exhalative sulfide deposits from Axial Seamount and Explorer Ridge, Northeastern Pacific Ocean. Canadian Mineralogist, vol. 28, part 1, p. 51-54.

Leitch, C.H.B., 1981a. Mineralogy and textures of the Lahanos and Kizikaya massive sulphide deposits, northeastern Turkey, and their similarity to Kuroko ores. Mineralium Deposita, vol. 16, # 2, p. 241-257.

Leitch, C.H.B., 1981b. Ore textures in Turkish volcanogenic massive sulphide deposits in light of exhalative sulfide deposits from Axial Seamount and Explorer Ridge, northeastern Pacific Ocean. The Canadian Mineralogist, vol. 28, part 1, p. 51-54.

Lentz, D. R., 1998. Petrogenetic evolution of felsic volcanic sequences associated with Phanerozoic volcanic-hosted massive sulphide systems: the role to extensional geodynamics. Ore Geology Reviews, vol. 12, p. 289-327.

Lo, B. and Gibson, A.M., 1999. Helicopter-borne EM, magnetic and VLF survey on the Wolf claims. Assessment Report 093955 written for Atna Resources Ltd. and YGC Resources Ltd.

MacLellan, M.L. and Carne, R.C., 1990. Final report, 1990 field program, Marg property, Yukon. Assessment Report 092915 written for NDU Resources Ltd. and Cameco Corporation.

MacRobbie, P.A., 1996a. 1995 Assessment Report, TIN property, soil geochemistry and geological mapping, Watson Lake Mining District, Pelly Mountains area. Assessment Report 093391 written for Cominco Ltd.

MacRobbie, P.A., 1996b. 1995 Assessment Report, MONY Property, line cutting, ground geophysical surveys (HLEM/mag), soil geochemistry and geological mapping, Watson Lake Mining District, Yukon, Money Creek area. Assessment Report 093428 written for Cominco Ltd.

MacRobbie, P.A., 1996c. 1995 Assessment Report, GO and NAD properties, soil geochemistry and geological mapping, Watson Lake Mining District, Yukon, Campbell Range area. Assessment Report 093402 written for Cominco Ltd.

MacRobbie, P.A., 1995a. 1994 Assessment Report on the Tin property, soil geochemistry and geological mapping, Watson Lake Mining District, Yukon. Assessment Report 093331 written for Cominco Ltd.

MacRobbie, P.A., 1995b. 1994 Assessment Report, Pop, Base, Home, Run, Ball, Fly and Bat properties, Linecutting, ground geophysics (HLEM/MAG and gravity), soil geochemistry and geological mapping, Watson Lake Mining District, Yukon. Assessment Report 093338 written for Cominco Ltd.

MacRobbie, P.A., 1995c. 1994 Assessment Report, Mony property, linecutting, ground geophysical surveys (HLEM/Mag), soil geochemistry and geological mapping, Watson Lake Mining District, Yukon, Money Creek area. Assessment Report 093324 written for Cominco Ltd.

MacRobbie, P.A., 1995d. 1995 Assessment Report, Expo property (including the Pop, Home, Run, Fly and Bat properties), linecutting, ground geophysics (HLEM/Mag and gravity), soil geochemistry and geological mapping, Watson Lake Mining District, Yukon, Fire Lake area, Pelly Mountains, NTS 105G/1. Assessment Report 093426 written for Cominco Ltd.

MacRobbie, P.A., 1995e. 1994 Assessment Report, Go and Nad properties, soil geochemsitry and geological mapping, Watson Lake Mining District, Yukon, Pelly Mountains area. Assessment Report 093336 written for Cominco Ltd.

MacRobbie, P.A., 1992. Fox-Wolf-Lynx property: soil geochemistry and geological mapping. Assessment Report 093017 written for Cominco Ltd.

MacRobbie, P.A., 1991. 1991 Assessment Report, Fox-Wolf-Lynx property, soil geochemistry and geological mapping, Watson Lake Mining District, Yukon. Assessment Report 093017 written for Cominco Ltd.

MacRobbie, P.A., and Senft, 1999. 1998 Assessment Report, Expo property (Expo south and Fly areas), geological mapping and soil geochemistry, Watson Lake Mining District, Yukon, Simpson Range area, Pelly Mountains, NTS 105G/1. Assessment Report 093972 written for Cominco Ltd.

McClelland, W.C., Gehrels, G.E., Samson, S.D. and Patchett, P.J., 1991. Protolith relations of the Gravuna belt and Yukon-Tanana Terrane in central southeastern Alaska. Journal of Geology, vol. 100, p. 107-123.

McGill, D.L., Lo, B. and Wilson, R.G., 1998. Helicopter borne EM, magnetic and VLF survey on the Fire 1-12, Char 1-30 and Tree 1-56 claims, Watson Lake Mining District. Assessment Report 093867 written for Atna Resources Ltd.

Metcalf, P., 1981. Petrogenesis of the Klondike formation, Yukon Territory. M.Sc. Thesis, University of Manitoba, Winnipeg, Manitoba, Canada.

Mihalynuk, M.G., Nelson, J. and Friedman, R.M., 1998. Regional geology and mineralization of the Big Salmon Complex (104N NE and 104O NW). *In:* Geological Fieldwork 1997, British Columbia Geological Survey Branch, Paper 1998-1, p. 6-1 to 6-20.

Morin, J.A., 1977. Ag-Pb-Zn mineralization in the MM deposit and associated Mississippian felsic volcanic rocks in the St. Cyr Range, Pelly Mountains. *In:* Mineral Industry Report, 1976, Yukon Territory. Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada 1977-1, p. 83-97.

Mortensen, J.K., 1996. Geological compilation maps of the Northern Stewart River map area, Klondike and Sixtymile districts (115N/15,16; 115O/13,14 and parts of 115O/15,16), 1:50,000 scale. Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada Open File 1996-1(G).

Mortensen, J.K., 1992a. Pre-mid-Mesozoic tectonic evolution of the YTT, Yukon and Alaska. Tectonics, vol. 11, p. 836-853.

Mortensen, J.K., 1992b. New U-Pb zircon ages for the Slide Mountain Terrane in southeastern Yukon Territory. *In:* Radiogenic Age and Isotopic Studies: Report 5, Geological Survey of Canada, Paper 91-2, p. 167-173.

Mortensen, J.K., 1990. Geology and U-Pb geochronology of the Klondike District, west-central Yukon Territory. Canadian Journal of Earth Science, vol. 27, p. 903-914.

Mortensen, J.K., 1988. Geology southwestern Dawson map area. Geological Survey of Canada, Open File 1927, 1:250 000 scale map.

Mortensen, J.K., 1983. Age and evolution of the YTT, southeastern Yukon Territory. Unpublished Ph.D. thesis, University of California, Santa Barbara.

Mortensen, J.K., 1982. Geological setting and tectonic significance of Mississippian felsic meta-volcanic rocks in the Pelly Mountains, southeastern Yukon Territory. Canadian Journal of Earth Sciences, vol. 19, p. 8-22.

Mortensen, J.K., 1981. Geological setting and tectonic significance of Mississippian felsic metavolcanic rocks in the Pelly Mountains, southeastern Yukon Territory. Canadian Journal of Earth Sciences, vol. 19, p. 8-22.

Mortensen, J.K., 1979. Stratigraphic, structural, and tectonic setting of an Upper Devonian-Mississippian volcanic-sedimentary sequence and associated base metal deposits in the Pelly Mountains, southeastern Yukon Territory. M.A.Sc. Thesis, University of British Columbia, Vancouver, British Columbia, 122 p.

Mortensen, J.K. and Thompson, R.I., 1989. A U-Pb zircon-baddelyite age for a differentiated mafic sill in the Ogilvie Mountains, west-central Yukon. *In:* Radiogenic age and isotopic studies: Report 3. Geological Survey of Canada, Paper 89-2.

Mortensen, J.K. and Jilson, G.A., 1985. Evolution of the YTT: Evidence from southeastern Yukon Territory. Geology, v. 13, # 11, p. 806-810.

Mortensen, J.K. and Godwin, C.I., 1982. Volcanogenic massive sulphide deposits associated with highly alkaline rift volcanics in the southeastern Yukon Territory. Economic Geology, vol. 77, #5, p. 1225-1230.

Murphy, D.C., 2001. Yukon-Tanana Terrane in southwestern Frances Lake area (105H/3,4 and 5), southeastern Yukon. *In:* Yukon Exploration and Geology, 2000; Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 217-233.

Murphy, D.C., 1998. Stratigraphic framework for syngenetic mineral occurrences, Yukon-Tanana Terrane south of Finlayson Lake: A progress report. *In:* Yukon Exploration and Geology, 1997; Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 51-58.

Murphy, D.C., 1997a. Preliminary geology map of Grass Lakes area, Pelly Mountains, southeastern Yukon (105G/7). Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Open File 1997-3, scale 1:50 000.

Murphy, D.C., 1997b. Geology of the McQuesten River region, northern McQuesten and Mayo map areas, Yukon Territory (115P/14, 15, 16; 105M/13, 14). Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Bulletin 6, 122 p.

Murphy, D.C., 1997c. Geology of the McQuesten River region, northern McQuesten and Mayo map area, Yukon Territory (115P/14, 15, 16; 105M/13, 14). Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Bulletin 6, 122 p.

Murphy, D.C., Colpron, M., Gordey, S.P., Roots, C., Abbott, J.G. and Lipovsky, P. S., 2001. Preliminary bedrock geological map of northern Finlayson Lake area (NTS 105G), Yukon Territory. Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Open File 2001-33, 1:100 000 scale.

Murphy, D.C. and Piercey, S.J., 2000. Syn-mineralization faults and their re-activation, Finlayson Lake massive sulphide district, Yukon-Tanana Terrane, southeastern Yukon. *In:* Yukon Exploration and Geology, 1999, D.E. Emond and L.H. Weston (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 55-66.

Murphy, D.C. and Piercey, S.J., 1999a. Finlayson project: geological evolution of Yukon-Tanana Terrane and its relationship to Campbell Range belt, northern Wolverine Lake map area, southeastern Yukon. *In:* Yukon Exploration and Geology, 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 47-62.

Murphy, D.C. and Piercey, S.J., 1999b. Geological map of parts of Finlayson Lake (105G/7,8 and parts of 1,2 and 9) and Frances Lake (parts of 105H/5 and 12) map areas, southeastern Yukon (1:100 000 scale). Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Open File 1999-4.

Murphy, D.C. and Piercey, S.J., 1999c. Geological map of Wolverine Lake area (105G/8), Pelly Mountains, southeastern Yukon (1:50,000 scale). Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Open File 1999-3.

Murphy, D.C. and Timmerman, J.R.M., 1997a. Preliminary geology of part of Grass Lakes map area (105G/7, northeast third). *In:* Yukon Exploration and Geology, 1996; Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 63-73.

Murphy, D.C. and Timmerman, J.R.M., 1997b. Preliminary geology map of part of Grass Lakes area, Pelly Mountains, southeastern Yukon (105G/7). Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Open File 1997-1, scale 1: 50,000.

NDU Resources Ltd., 1996. Yukon Mineral Interest being acquired. George Cross News Letter, 1996. No.5, p. 1.

Nelson, J., 1999. Devono-Mississippian VMS project: continuing studies in the Dorsey Terrane, northern British Columbia. *In:* Geological Fieldwork 1998, British Columbia Geological Survey Branch, Paper 1999-1, p. 143-155.

Nelson, J., 1997. Last seen heading south: extensions of the YTT into northern British Columbia. *In:* Geological Fieldwork 1996, British Columbia Geological Survey Branch, Paper 1997-1, p. 145-156.

Nelson, J., Harms, T. and Mortensen, J., 1998. Extensions and affiliates of the Yukon-Tanana Terrane in northern British Columbia. *In:* Geological Fieldwork 1997, British Columbia Geological Survey Branch, Paper 1998-1, p. 7-1 to 7-12.

Nelson, J. and Mihalynuk, M., 1993. Cache Creek ocean: closure or enclosure? Geology, 21, p. 173-176.

Newberry, R.J., Crafford, T.C., Newkirk, S.R., Young, L.E., Nelson, S.W. and Duke, N.A., 1997. Volcanogenic massive sulphide deposit of Alaska. *In:* Mineral Deposits of Alaska, R.J. Goldfarb and L.D. Miller (eds.), Economic Geology, Monograph 9, p. 120-150.

Norman, G. and Vyselaar, J., 1979. Combined geological, geochemical and geophysical report, Tree claim group, Watson Lake Mining Division. Assessment Report 090455 written for Utah Mines Ltd.

Olfert, E.G., 1981. Geochemical report on the Bronson claims 1-10, Dawson Mining District, Yukon Territory. Assessment Report 090773 written for Cominco Ltd.

Olfert, E.G., 1980. Geochemical and trenching report on the Holly 1-47 claims, Dawson Mining District, Yukon Territory. Assessment Report 090698 written for Cominco Ltd.

Olfert, E.G., 1979. Geological and geochemical report on the Clip group of mineral claims, Dawson Mining District, Yukon Territory. Assessment Report 090491 written for Cominco Ltd.

Orchard, M.J., 1994. Report on conodonts and other microfossils – Geological Survey of Canada samples 093513a,b. Report MJO-1994-6. *In:* Poulton, T., Orchard, M.J., Gordey, S.P., and Davenport, P. (compilers), 1999, Yukon fossil determinations. *In:* Yukon digital Geology, S.P. Gordey and A.J. Makepeace (comp.), Geological Survey of Canada, Open File D3826, or Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Open File 1999-1 (D).

Payne, J.G., 1996a. Report #960632, Finlayson project, Ice property. Report by Vancouver Petrographics Ltd.

Payne, J.G., 1996b. Report #960714, Finlayson project, Ice property. Report by Vancouver Petrographics Ltd.

Pearce, J.A., Harris, N.B.W. and Tindle, A.G., 1984. Trace element discrimination diagrams for the tectonic interpretation of granitic rocks. Journal of Petrology, vol. 25, p. 956-983.

Piercey, S.J., Peter, J.M., Bradshaw, G.D., Tucker, T. and Paradis, S., 2001. Geological characteristics of high-level subvolcanic porphyritic intrusions associated with the Wolverine Zn-Pb-Cu-Ag-Au volcanic-hosted massive sulphide deposit, Finlayson Lake district, Yukon, Canada. *In:* Yukon Exploration and Geology, 2000, D.E. Emond and L.H. Weston (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 335-346.

Piercey, S.J. and Murphy, D.C., 2000. Stratigraphy and regional implications of unstrained Devono-Mississippian volcanic rocks in the Money Creek thrust sheet, Yukon-Tanana Terrane, southeastern Yukon. *In:* Yukon Exploration and Geology, 1999, D.E. Emond and L.H. Weston (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 67-78.

Piercey, S.J., Hunt, J.A. and Murphy, D.C., 1999. Lithogeochemistry of meta-volcanic rocks from Yukon-Tanana Terrane, Finlayson Lake region, Yukon: preliminary results. *In:* Yukon Exploration and Geology, 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 125-138.

Pigage, L., 1997. Mapping and stratigraphy at Ice. Expatriate Resources Ltd., Unpublished Internal Company Report, 5 p.

Pigage, L., 1996a. The Ice Property. Oral presentation given at the Geoscience Forum, Whitehorse, Yukon Territory, November 26, 1996.

Pigage, L.C., 1996b. Assessment Report describing drilling on the Red Line property, NTS 105G/8 in the Watson Lake Mining District, Yukon Territory. Assessment Report 093585 written for Expatriate Resources Ltd.

Plint, H.E. and Gordon, T.M., 1997. The Slide Mountain Terrane and the structural evolution of the Finlayson Lake fault zone, southeastern Yukon. Canadian Journal of Earth Science, vol. 34, p. 105-126.

Plint, H.E. and Gordon, T.M., 1996. Structural evolution and rock types of the Slide Mountain and Yukon-Tanana terranes in the Campbell Range, southeastern Yukon Territory. *In:* Current Research 1996-A; Geological Survey of Canada, p. 19-28.

Plouffe, A., 1989. Drift prospecting and till geochemistry in Tintina Trench, southeastern Yukon, M.Sc. Thesis, Carleton University, Ottawa, Ontario, 103 p.

Plouffe, A. and Jackson, L.E., 1995. Drift prospecting for gold in the Tintina Trench, near Faro and Ross River, Yukon Territory. *In:* Drift Exploration in the Canadian Cordillera, P.T. Bobrowsky, S.J. Sibbick, J.M. Newell and P.F. Matysek (eds), British Columbia Ministry of Energy, Mines and Petroleum Resources, Paper 1995-2, p. 53-66.

Plouffe, A. and Jackson, L.E., 1992. Drift prospecting for gold in the Tintina Trench. *In:* Yukon Geology, vol. 3, Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 196-213.

Pride, K.R., 1996a. Fan property, NTS 116C/10 Y.T. Geological and Geochemical survey. Assessment Report 093485 written for Cominco Ltd.

Pride, K.R., 1996b. Combined helicopter-borne magnetic and electromagnetic survey and soil geochemical survey, Coal property, NTS 116C/8. Assessment Report 093480 written for Cominco Ltd.

Pride, K.R., 1996c. Pup property, NTS 116B/4. Assessment Report 093496 written for Cominco Ltd.

Pride, K.R., 1996d. Floc property, combined helicopter-borne magnetic and electromagnetic survey and soil and rock geochemical survey, NTS 116B/4. Assessment Report 093478 written for Cominco Ltd.

Robertson, R., 2000. Expatriate inks deal to acquire Kudz Ze Kayah. The Northern Miner, vol. 86, # 2, March 6-12.

Robitaille, A. and Thompson, A.J.B., 1999. Mineral identification using PIMA, SEM, and XRD. Internal report prepared for Craig Hart and Julie Hunt, Yukon Geology Program by PetraScience Consultants Inc.

Roddick, J.A., 1967. Tintina Trench. Journal of Geology, vol. 75, p. 23-33.

Roots, C.F., 1997. Geology of the Mayo map area, Yukon Territory (105M). Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs, Canada, Bulletin 7, 82 p.

Sax, K. and Carne, R.C., 1990. Summary report on 1991 exploration, Matson Creek property, Dawson Mining District. Assessment Report 092953 written for YGC Resources Ltd.

Schmidt, U., 1998. Report on soil geochemical survey and geology of the Tree 1-28 claims, Tree property, Watson Lake Mining District. Assessment Report 093777 written for Atna Resources Ltd.

Schmidt, U., 1997. Report on geology, grid soil geochemical survey and diamond drilling of the Wolf 18 claim, Wolf property, Watson Lake Mining District. Assessment Report 093648 written for Atna Resources Ltd.

Schmidt, U., 1996a. Report on 1995 soil geochemical survey of the Pub claims, Dawson Mining District. Assessment Report 093463 written for Atna Resources Ltd.

Schmidt, U., 1996b. Report on 1995 soil geochemical survey of the Bal claims, Dawson Mining District. Assessment Report 093464 written for Atna Resources Ltd.

Schmidt, U., 1996c. Report on 1995 soil geochemical survey of the Matson Creek property, BOR 31 claim, Dawson Mining District. Assessment Report 093462 written for Atna Resources Ltd.

Schmidt, U., 1996d. Report on 1995 grid soil geochemical survey of the Mic property, Dawson Mining District. Assessment Report 093461 written for Atna Resources Ltd.

Schmidt, U., 1995. A preliminary evaluation of the Ty claims, Finlayson Lake area, Yukon Territory, NTS 105G/1, Watson Lake Mining District. Forms part of Assessment Report 093430 written for Pacific Bay Minerals Ltd.

Schultze, H.C., 1996a. Summary of the KZK project, volcanic hosted massive sulphide deposit, Yukon Territory. *In:* Yukon Exploration and Geology 1995; Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 29-31.

Schultze, H.C., 1996b. Talk given at the Geological Association of Canada volcanogenic massive sulphide workshop, November 14th, 1996 at Simon Fraser University Downtown Campus, Vancouver, British Columbia.

Schultze, H.C. and Hall, D.C., 1997. 1996 Assessment Report, KZK property, Linecutting, soil geochemistry, geological mapping, geophysical surveys and diamond drilling, Watson Lake M.D., Yukon, North Lakes Area, work period May 30 to August 30, 1996. Assessment Report 093712 written for Cominco Ltd.

Sebert, C., 1997. Geological results. Unpublished report, accompanying stereonets and photomicrographs for Columbia Gold Mines Ltd., October, 1997.

Sebert, C., Hunt, J.A., and Foreman, I.J., in prep. Geology and lithogeochemistry of the Fyre Lake Cu-Co-Au sulphide-magnetite deposit, southeastern Yukon. Submitted for Open File report to Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada.

Sebert, C. and Hunt, J.A., 1999. A note on preliminary lithogeochemistry of the Fire Lake area. *In:* Yukon Exploration and Geology, 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 139-142.

Senft, D.A., 1997. 1996 Assessment Report, Mony and Nad properties, linecutting, ground geophysical surveys (HLEM/mag+/-gravity), soil geochemistry, geological mapping/prospecting and diamond drilling, Watson Lake Mining District, Yukon, Money Creek area. Assessment Report 093613 written for Cominco Ltd.

Shearer, J.T., 1997. Petrographic descriptions for Ice property, Finlayson project. Report by Vancouver Petrographics Ltd. for Expatriate Resources Ltd., June 28, 1995.

Shervais, J.W., 1982. Ti-V plots and the petrogenesis of modern and ophiolitic lavas. Earth and Planetary Science Letters, vol. 59, p. 101-118.

Stevens, R.A., 1992. Regional geology, fabric and structure of the Teslin suture zone in Teslin map area, Yukon Territory. *In:* Current Research, Geological Survey of Canada, Paper 92-1A, p.287-296.

Stevens, R.A., Erdmer, P., Creaser, R.A. and Grant, L.S., 1996. Mississippian assembly of the Nisutlin Assemblage: evidence from primary contact relationships and Mississippian magmatism on the Teslin tectonic zone, part of the Yukon-Tanana Terrane of south-central Yukon. Canadian Journal of Earth Sciences, vol. 33, p. 103-116.

Stevens, R.A. and Harms, T.A., 1995. Investigations in the Dorsey Terrane, part 1: stratigraphy, structure and metamorphism in the Dorsey Terrane, southern Yukon Territory and northern British Columbia. *In:* Current Research, Geological Survey of Canada, Paper 95-1A, p. 117-128.

Stevens, R.A. and Erdmer, P., 1993. Geology and structure of the Teslin suture zone and related rocks in part of Laberge, Quiet Lake and Teslin map areas, Yukon. *In:* Current Research, Geological Survey of Canada, Paper 93-1A, p. 20-22.

Stroshein, R.W., 1991. Geology, geochemical and geophysical report on the Kona property, Watson Lake Mining District, Yukon Territory. Assessment Report 092991.

Syzbiniski, Z.A., 1996. Structural analysis of KZK area. Cominco Ltd. Internal File Note.

Taylor, S.R. and McLennan, S.M., 1985. The continental crust: its composition and evolution. Blackwell Scientific Publications, Oxford, 312 p.

Tempelman-Kluit, D.J., 1979. Transported cataclasite, ophiolite and granodiorite in Yukon: evidence of arc-continent collision. Geological Survey of Canada Paper 79-14, 27 p.

Tempelman-Kluit, D.J., 1977a. Quiet Lake (105F) and Finlayson Lake (105G) map areas. GSC Open File 486, scale 1:250,000.

Tempelman-Kluit, D.J., 1977b. Stratigraphic and structural relations between the Selwyn Basin, Pelly-Cassiar Platform, and Yukon Crystalline Terrane in the Pelly Mountains, Yukon. Geological Survey of Canada, Paper 77-1A, p. 223-227.

Tempelman-Kluit, D.J., 1976. The Yukon Crystalline Terrane: Enigma in the Canadian Cordillera. Geological Society of America Bulletin, vol. 87, p. 1343-1357.

Tempelman-Kluit, D.J., 1972. Geology and origin of the Faro, Vangorda and Swim concordant zinc-lead deposits, central Yukon Territory. Geological Survey of Canada Bulletin, 208, 73 p.

Tempelman-Kluit, D.J. and Blusson, S.L., 1977. Pelly-Cassiar Platform and Selwyn Basin: neither without the other. Geological Association of Canada, Annual Meeting, Program with Abstracts, vol. 2, p. 52.

Tempelman-Kluit, D.J., Gordey, S.P., and Read, B., 1976. Stratigraphic and structural studies in the Pelly Mountains, Yukon Territory. Geological Survey of Canada, Paper 76-1A, p. 97-106.

Terry, D.A., 1998. Wika/Yt property 1997 Assessment Report describing geological surveys on the Yt (86-91) claims, Finlayson Lake area, Yukon Territory, NTS 105G/1, Watson Lake Mining Division. Assessment Report 093801 written for Westmin Resources Limited.

Terry, D.A. and Gale, D., 1998. Ty property 1997 Assessment Report describing geological, geochemical, and geophysical surveys on the Ty 1-38 claims, Finlayson Lake area, Yukon Territory, NTS 105G/1, Watson Lake Mining Division. Assessment Report 093822 written for Westmin Resources Limited.

Terry, D.A., Turner, A., Bradshaw, G.D. and Tucker, T.L., 1997b. 1996 Assessment Report describing geological, geochemical, geophysical and diamond drill hole surveys on the Wika (1-64) and Yt (1-91) claims, Finlayson Lake area, Yukon Territory, NTS 105G/1, Watson Lake Mining Division. Assessment Report 093592 written for Westmin Resources Limited.

Terry, D.A., Turner, A.J., Bradshaw, G.D. and Tucker, T.L., 1996. 1996 Assessment Report describing geological, geochemical, geophysical and diamond drill hole surveys on the Ty 1-38 claims, Finlayson Lake area, Yukon Territory, NTS 105G/1, Watson Lake Mining Division. Assessment Report 093623 written for Westmin Resources Limited.

Tucker, T.L., Turner, A.J., Terry, D.A. and Bradshaw, G.D., 1997a. Wolverine massive sulphide project, Yukon Territory, Canada. *In:* Yukon Exploration and Geology, 1996; Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 53-55.

Tulk, L.A., 1997. 1996 Assessment Report, Expo property (including the Pop, Home, Run and Fly properties), picketing, ground geophysics (HLEM/Mag), soil geochemistry and geological mapping, Watson Lake Mining District, Yukon, Fire Lake area, Pelly Mountains, NTS 105G/1. Assessment Report 093581 written for Cominco Ltd.

Turner, A.J. and Terry, D.A., 1998a. 1997 summary report on the Foot 1-20, 37-80, 83-94, 180-188, 215-231, 11A-12A, Kink 3, Low 13-14 located in the Pelly mountains, Watson Lake Mining District. Assessment Report 093779 written for Westmin Resources Limited, 6 volumes.

Turner, A.J. and Terry, D.A., 1998b. 1997 summary report ground geophysical and geochemical, and diamond drill programs conducted on the Puck 1-80 and Cup 1-24 claims, Finlayson Lake area, Yukon Territory, Watson Lake Mining District. Assessment Report 093790 written for Westmin Resources Limited, 2 volumes.

Turner, R.J.W. and Abbott, G., 1990. Regional setting, structure, and zonation of the Marg volcanogenic massive sulphide deposit, Yukon. Geological Survey of Canada Paper 90-1E, p. 31-41.

Van Randen, J., 1997. Unpublished petrographic report on Fyre Lake for the Yukon Geology Program.

Wengzynowski, W.A., 1999a. Assessment Report describing geological mapping and prospecting at the Slap Shot property, NTS 105G/7, Watson Lake Mining District, Yukon Territory. Assessment Report 093995 written for Expatriate Resources Ltd.

Wengzynowski, W.A., 1999b. Assessment Report describing geological mapping, prospecting and soil geochemistry on the Goal Net property (Blade 1-106, Goal 1-335, Goon 1-136, Net 1-214, NHL 1-176, Overtime 1-86), NTS 105G/7 and 8 in the Watson Lake Mining District, Yukon Territory. Assessment Report 094016 written for Expatriate Resources Ltd.

Wengzynowski, W.A., 1998a. Assessment Report describing geological mapping, prospecting and soil sampling at the Slap Shot property, NTS 105G/7, Watson Lake Mining District, Yukon Territory. Assessment Report 093818 written for Expatriate Resources Ltd.

Wengzynowski, W.A., 1998b. Assessment Report describing geological mapping, soil sampling and hand trenching at the Hat Trick property on NTS 105G/2 & 7 in the Watson Lake Mining District, Yukon Territory. Assessment Report 093811 written for Expatriate Resources Ltd.

Wengzynowski, W.A., 1998c. Assessment Report describing soil sampling and hand trenching at the League property on NTS 105G/10 in the Watson Lake Mining District, Yukon Territory. Assessment Report 093817 written for Expatriate Resources Ltd.

Wengzynowski, W.A., 1996a. Assessment report describing prospecting and geochemical surveys on the GOAL and NET Claims, Watson Lake Mining District. Assessment Report 093413 written for Archer, Cathro and Associates (1981) Ltd.

Wengzynowski, W.A., 1996b. Assessment Report describing prospecting and geochemical surveys on the Hat Trick property, Hat Trick 1-50, NTS 105G/2 in the Watson Lake Mining District, Yukon Territory. Assessment Report 093492 written for Expatriate Resources Ltd.

Wengzynowski, W.A., 1996c. Assessment Report describing prospecting, geochemical and geophysical surveys on the Red Line property, NTS 105G/8 in the Watson Lake Mining District, Yukon Territory. Assessment Report 093491 written for Expatriate Resources.

Westmin Resources Limited, 1998. Press release on reserves at Wolverine, 15/01/98.

Westmin Resources Limited and Atna Resources Ltd., 1997. Joint news release: New discovery on Sable Zone, step out holes extend Wolverine deposit to the east. Press Release, Sept. 4, Vancouver, B.C.

Westmin Resources Limited, 1996. Promotional material from Westmin Resources Limited, June 19, 1996. Document MISC/96-024.

Wheeler, J.O. and McFeely, P., 1991. Tectonic assemblage map of the Canadian Cordillera and adjacent parts of the United States of America. Geological Survey of Canada, Map 1712A, scale 1:2,000,000.

Wheeler, J.O. and McFeely, P., 1987. Tectonic assemblage map of the Canadian Cordillera and adjacent parts of the United States of America. Geological Survey of Canada, Open File 1565.

Wheeler, J O, Brookfield, A J., Gabrielse, H., Monger, J. W. H., Tipper, H. W. and Woodsworth, G. J. 1991: Terrane Map of the Canadian Cordillera; Geological Survey of Canada, "A" Series Map, 1713A.

Wheeler, J O, Brookfield, A J., Gabrielse, H., Monger, J. W. H., Tipper, H. W. and Woodsworth, G. J. 1988: Terrane Map of the Canadian Cordillera; Geological Survey of Canada, Open File, 1894.

Wheeler, J.O., Green, L.H. and Roddick, J.A., 1960a. Sheet 105G - Finlayson Lake Map Area. Geological Survey of Canada Map 8-1960.

Wheeler, J.O., Green, L.H. and Roddick, J.A., 1960b. Sheet 105F – Quiet Lake Map Area. Geological Survey of Canada Map 7-1960.

Whiteway, P., 1995. Fast tracking ABM. *In:* Canadian Mining Journal, June 1995, p. 17-21.

Wilson, J. and Westerman, C.J., 1978. Combined geological and geochemical report, Tree claim group, Watson Lake Mining Division. Assessment Report 090322 written for Utah Mines Ltd.

Wilson, R.G. and Holbek, P., 1999. 1998 project report on the Ice (Bnob) property. Assessment Report 093958 written for Atna Resources Ltd.

Wilson, R.G. and Holbek, P., 1998. 1997 project report on the Money property, Yukon Territory. Assessment Report 093960 written for Atna Resources Ltd. and YGC Resources Ltd.

Winchester, J.A. and Floyd, P.A., 1977. Geochemical discrimination of different magma series and their differentiation products using immobile elements. Chemical Geology, vol. 20, p. 325-343.

Woolham, R.W., 1996. Report on a combined helicopter-borne electromagnetic and magnetic survey, Goal Net, Hat Trick, League, Offside, Power Play, Shutout and Slapshot properties, Finlayson Lake area, Yukon Territory, NTS 105G & J. Assessment Report 093655 written for Expatriate Resources Limited.

Woolham, R.W., 1995a. Combined helicopter-borne magnetic and electromagnetic survey, Yukon Territory, Swde property. Assessment Report 093479 written for Cominco Ltd.

Woolham, R.W., 1995b. Combined helicopter-borne magnetic and electromagnetic survey, Yukon Territory, Bruin property. Assessment Report 093481 written for Cominco Ltd.

Yukon MINFILE, 2001. Database of Yukon mineral occurrences. Exploration and Geological Services, Yukon Region, Indian and Northern Affairs Canada.

© Minister of Public Works and Government Services Canada, 2002, ISBN 0-662-32198-7

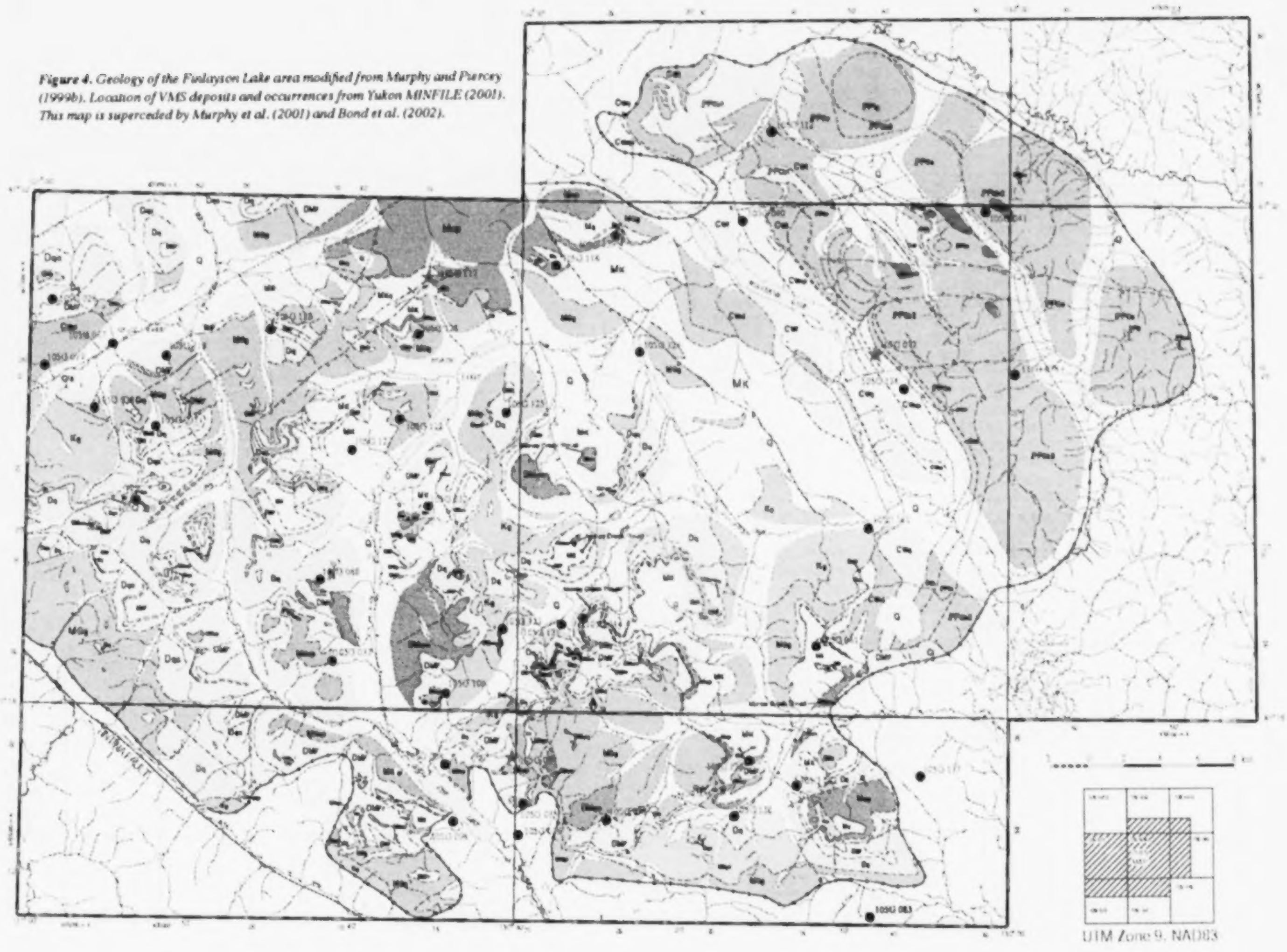


Figure 4. Geology of the Finlayson Lake area modified from Murphy and Piercey (1999b). Location of VMS deposits and occurrences from Yukon MINFILE (2001). This map is superceded by Murphy et al. (2001) and Bond et al. (2002).

QUATERNARY

Q	Unconsolidated alluvium, colluvium, lacustrine and glacial deposits
Qls	Landslide

INTRUSIVE ROCKS

CRETACEOUS[1]

Kg	Weakly foliated, medium- to coarse-grained biotite muscovite granite, generally equigranular

PERMIAN

■	Rare, tan to white foliated granitic dykes

PENNSYLVANIAN to PERMIAN

PPlg	Whitish green leucogabbro
PPum	Brown weathering, dark green to black, variably serpentinized ultramafic rock. Intrusive contacts are locally preserved

MISSISSIPPIAN[2, 3]

SIMPSON RANGE PLUTONIC SUITE

MSg	Generally unfoliated biotite hornblende granite and quartz monzonite, locally faulted, chloritized and hematized
MSgm	Strongly foliated and lineated mylonitic MSg
MSgd	Hornblende granodiorite, locally faulted, chloritized and hematized. Intruded by MSg

GRASS LAKES PLUTONIC SUITE

MGg	Strongly foliated and lineated medium- to coarse-grained granitic to monzonitic metaplutonic rock. Generally equigranular although augen texture locally present. Locally discordant with earliest foliation

DEVONIAN to MISSISSIPPIAN[4]

DMg	Mafic poor quartz porphyritic granite. Cross cutting relationships between granite and subvolcanic feeder dykes to DMF basalt flows suggests that granite and basalt are coeval and that granite is likely coeval with unit DMFr. Intruded by MSg
DMum **DMgb**	Brown weathering, dark green to black, variably serpentinized ultramafic rock. Gabbro (DMgb) and/or pyroxenite locally present. In both hangingwall and footwall of the Money Creek Thrust, the unit is generally spatially associated and inferred to be in intrusive contact with DMF. In the footwall, the unit is also locally surrounded by unit Dq, also presumably with intrusive contacts. The unit locally occurs as isolated klippe of the Money Creek Thrust sheet and along the Money Creek Thrust itself as light coloured fish-scale talc serpentine schist
DMd	Foliated coarse grained hornblende biotite meta-diorite[5]

LAYERED ROCKS

PENNSYLVANIAN to PERMIAN (and possibly younger)[6]

CAMPBELL RANGE SUCCESSION

PPCb2	Coarse basaltic breccia, pillowed and massive basaltic lavas, gabbro, diabase, maroon and green chert. Foliated and tightly folded at eastern edge of Campbell Range Belt
PPCs **PPCl**	Carbonaceous argillite, sandstone and grey quartz grit, diamictite; top is marked by several metres of green, possibly tuffaceous chert and cherty argillite. These strata pass to the northeast into varicoloured chert and argillite, chert pebble conglomerate and Pennsylvanian[9] limestone (**PPCl**), possibly as olistoliths in conglomerate.
PPCb1	Coarse basaltic breccia, pillowed and massive basaltic lavas, gabbro, diabase, maroon and green chert. Foliated and tightly folded at eastern edge of Campbell Range Belt

CARBONIFEROUS

WOLVERINE LAKE SUCCESSION

Cwt **Cwl**	Thinly interbedded (cm scale), massive to granular siliceous rock and light coloured phyllite (metatuff and exhalite). Siliceous rock is pale coloured, locally massive and bedded on metre scale at base where associated with banded iron formation. Darker near top where intercalated phyllite is dark grey. One band of platy brown limestone (Cwl) was found in upper part of unit.
Cwcp	Carbonaceous phyllite and quartz sandstone with black glassy quartz grains. Includes some siliceous phyllite and quartz feldspar augen phyllite of volcanic or subvolcanic intrusive protolith.
Cw / Cwq	Tan to grey muscovite-quartz phyllite (Cw) and quartz feldspar augen phyllite (Cwq) of felsic volcanic and subvolcanic intrusive protolith.
Cws	Salt and pepper grey to dark grey coarse feldspathic mica sandstone and grit. Shale chips are common locally.

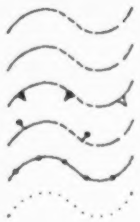
UNCONFORMITY

MISSISSIPPIAN[7]

GRASS LAKES SUCCESSION

Mcp	Carbonaceous phyllite and quartzite, minor quartzofeldspathic psammite.
Mm	Biotite chlorite[8] schist
Mq	Tan, white, mottled quartzite.
Mcg	Feldspar blue quartz pebble conglomerate.
MK **MKq** **MKcp**	Kudz Ze Kayah felsic metavolcanic unit: undifferentiated feldspar muscovite quartz[8] schist, feldspar and less commonly quartz augen schist (MKq). Carbonaceous phyllite (MKcp) locally important. Magnetite iron formation locally occurs near top of unit in carbonaceous phyllite and thin felsic schist.

SYMBOLS



Geological contact
(defined, approximate, assumed under cover)

Fault, displacement unknown
(defined, approximate, assumed under cover)

Fault, reverse (teeth on hanging wall)
(defined, approximate, assumed under cover)

Fault, normal (ball on downthrown hanging wall)
(defined, approximate, assumed under cover)

Limit of Mapping

Limit of Outcrop

---

[1] ca. 112 Ma U-Pb age determinations reported from similar bodies elsewhere in the Pelly Mountains (Mortensen, 1992 and personal communication, 1996)
[2] Mortensen, 1992 and personal communications, 1996-1999.)
[3] Grant, Greene and Erdmer (1996); Grant (1997)
[4] Mortensen (1991)
[5] Concordant 365 Ma U-Pb age (J. Mortensen, personal communication, 1996)
[6] Mid Pennsylvanian to Early Permian, based on radiolarians identified by Tekla Harms as reported in Plint and Gordon (1997)
[7] Tempelman-Kluit (1979)
[8] Mineral modifiers are listed in order of increasing abundance.
[9] Based on conodonts collected by Derek Rhodes, Cominco Ltd. and identified by Mike Orchard, GSC (Report No. MJO-1997-14)
[10] Hunt and Roddick (1997)

DEVONIAN to EARLY MISSISSIPPIAN

Cl	In Money Creek Thrust sheet, medium grey to white, massive to foliated limestone, locally with crinoid and other fossil fragments[10]
DMF **DMFr** **DMFcp**	Fire Lake mafic metavolcanic unit: In the footwall of the Money Creek Thrust, the unit comprises massive to subtly layered biotite plagioclase actinolite chlorite[8] schist, and lesser carbonaceous phyllite and quartzite and grey marble. Southwest of Fire Lake and in core of the Fyre Lake deposit, the unit contains quartz rich schist of probably volcanic or volcaniclastic protolith (DMFr). In the Money Creek Thrust sheet, in a large roof pendant of MSg, unit is tilted but essentially undeformed. In this setting, it comprises massive to pillowed basalt, maroon and green fragmental basalt, pink and green shale and cherty shale, tan greywacke and a middle member of pink to brown locally quartz porphyritic rhyolite (DMFr). Cross cutting relationships between dykes feeding basalt and dykes of DMg feeding unit DMFr indicate that they are coeval. Outside of the pendant, the unit is foliated and lineated, and contains mappable bands of carbonaceous phyllite and quartzite, pale green chert and grey marble (DMFcp).
Dq **Dqc** **Dm** **Df**	Biotite muscovite feldspar quartz[8] schist, micaceous quartzite and psammite, quartz biotite muscovite[8] metapelitic schist, and marble. Marble is locally thick and continuous enough to map as a separate member (Dm). Biotite plagioclase actinolite chlorite schist (Dqc) and feldspar muscovite quartz schist of probable volcanic protolith (Df) occur locally.

NET	Claim block (name shown on overlay)
▨	Land claim selection
● 105G 140	Yukon MINFILE (2001) occurrence
★ 105G 034	VMS deposit

Topographic base produced by
SURVEYS AND MAPPING BRANCH
DEPARTMENT OF ENERGY, MINES
AND RESOURCES

Copyright Her Majesty the Queen
in Right of Canada

FIVE THOUSAND METRE
Universal Transverse Mercator Grid
ZONE 8
North American Datum 1927

Figure 4. Legend to accompany map and overlay.

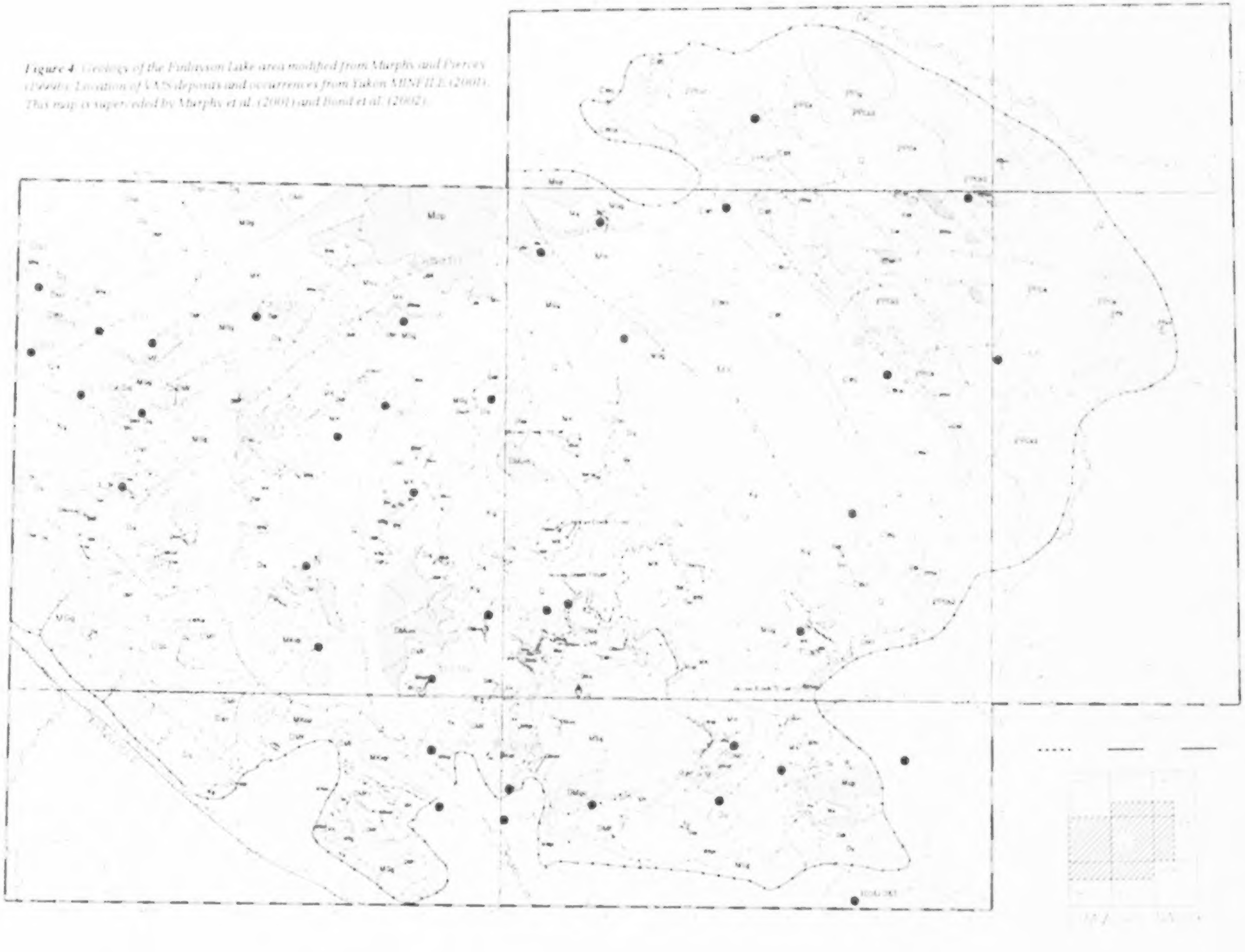


Figure 4. Geology of the Finlayson Lake area modified from Murphy and Piercey (1999b). Location of VMS deposits and occurrences from Yukon MINFILE (2001). This map is superceded by Murphy et al. (2001) and Bond et al. (2002).

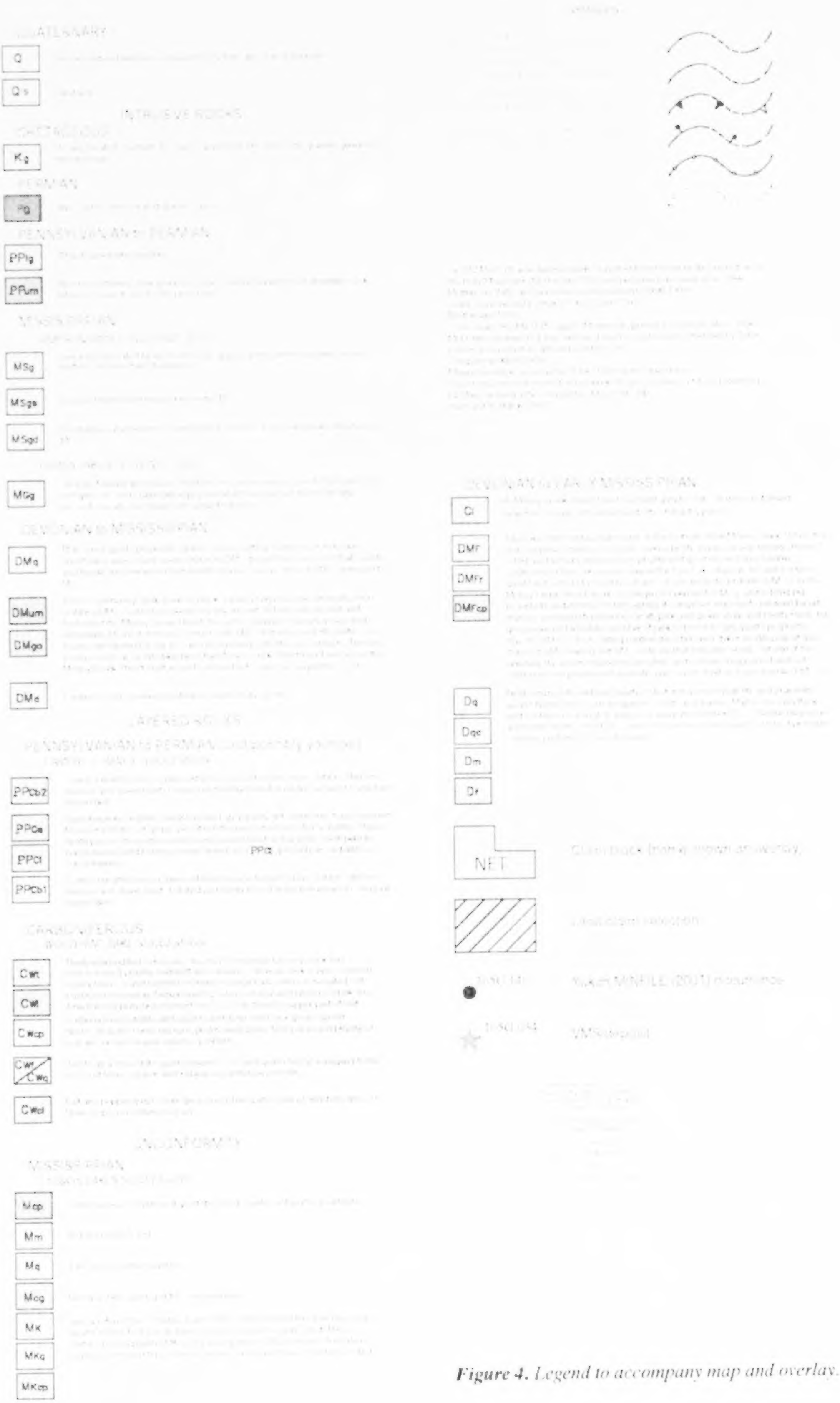

QUATERNARY
Q
Qs
INTRUSIVE ROCKS
CRETACEOUS
Kg
PERMIAN
Pg
PENNSYLVANIAN to PERMIAN
PPlg
PPum
MISSISSIPPIAN
MSg
MSga
MSgd
MGg
DEVONIAN to MISSISSIPPIAN
DMq
DMum
DMgo
DMd
LAYERED ROCKS
PENNSYLVANIAN to PERMIAN
PPcb2
PPca
PPct
PPcb1
PPct
CARBONIFEROUS
Cwt
Cwt
Cwcp
Cwt
Cwq
Cwd
UNCONFORMITY
MISSISSIPPIAN
Mcp
Mm
Mq
Mcg
Mk
Mkq
Mkcp
SYMBOLS
DEVONIAN to EARLY MISSISSIPPIAN
Ct
DMf
DMfr
DMFcp
Dq
Dqc
Dm
Df
NET
Clast block (name) shown on overlay
Yukon MINFILE (2001) occurrence
VMS deposit

Figure 4. *Legend to accompany map and overlay.*

© Minister of Public Works and Government Services Canada 2002. ISBN 0-662-32198-7